ANALYSIS OF PROXIMAL FEMUR GEOMETRY IN SOUTH INDIAN POPULATION USING COMPUTED TOMOGRAPHY

Dissertation submitted in

Partial fulfilment of the regulations required for the award of

M.S. Degree in Orthopaedics

THE TAMIL NADU Dr M.G.R. MEDICAL UNIVERSITY

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April 2015

CERTIFICATE

CERTIFICATE

This is to certify that the dissertation entitled "**ANALYSIS OF PROXIMAL FEMUR GEOMETRY IN SOUTH INDIAN POPULATION USING COMPUTED TOMOGRAPHY**" is a bonafide and genuine research work Carried out by **Dr. Saravana Kumar.J** in partial fulfilment of the requirement for the degree of Master of Surgery in Orthopaedics

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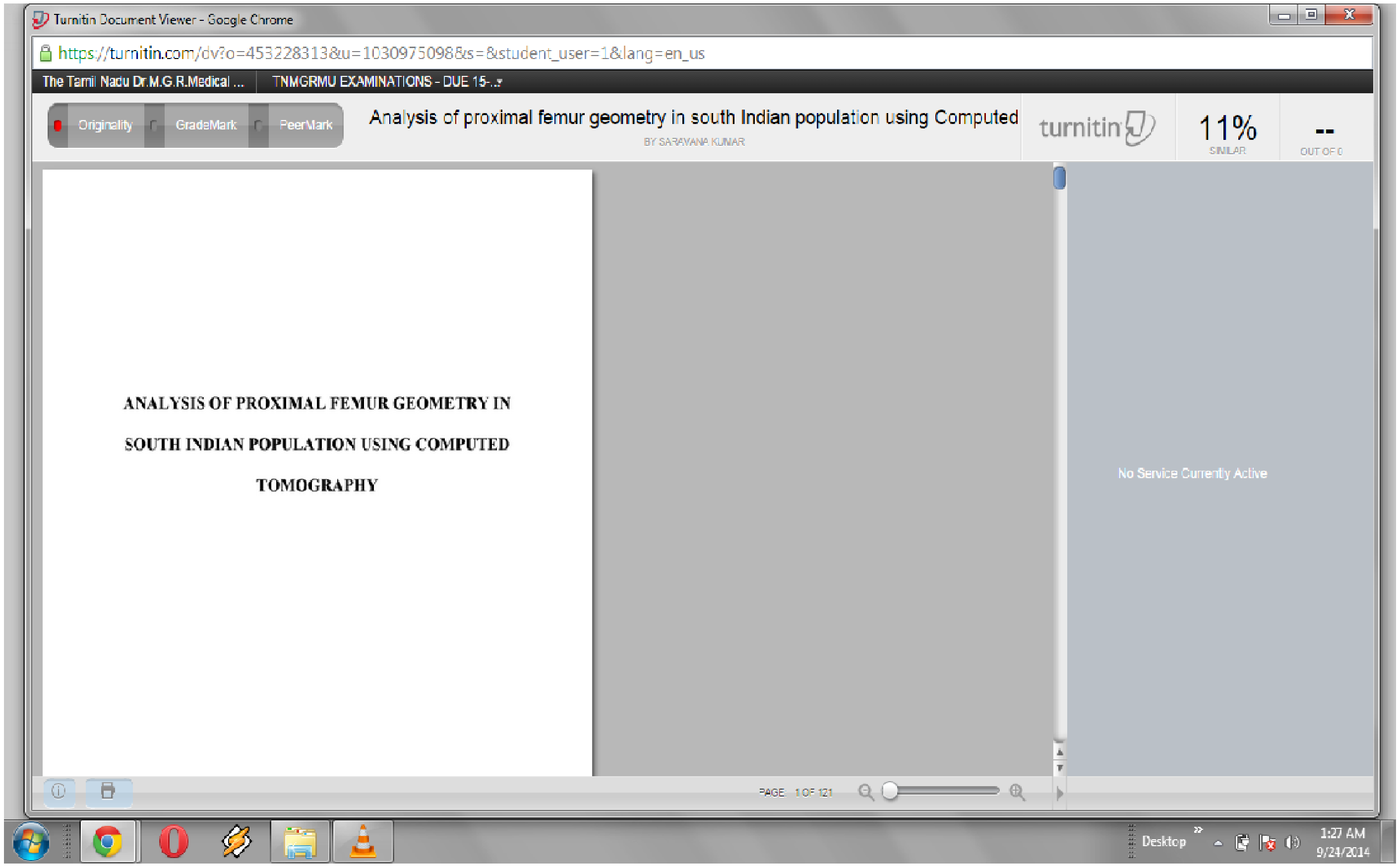
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DECLARATION

DECLARATION

I declare that this dissertation titled "**ANALYSIS OF PROXIMAL FEMUR GEOMETRY IN SOUTH INDIAN POPULATION USING COMPUTED TOMOGRAPHY**" has been prepared by me, at Coimbatore Medical College Hospital under the guidance of **Prof. Dr. S. Vetrivel Chezian,** Coimbatore Medical College Hospital, Coimbatore, in partial fulfilment of Dr. M.G.R. Tamilnadu Medical University, regulations for the award of M.S. Degree in Orthopaedics.

I have not submitted this dissertation to any other university for the award of any degree or diploma previously.

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Dr. Saravana kumar J,

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ABSTRACT

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BACKGROUND:

Standard commercially available implants and prosthesis may not be the best fit for Indian population due to large anatomic variation. Orthopedic surgeons always stress the need for proper sized implants. But at present the commercially available implants are designed for western population. Due to this mismatch, complications like aseptic loosening, screw pullout, discomfort, pain, non-union, malunion, avascular necrosis, improper load distribution and ultimately implant failure may arise.

PATIENTS AND METHODS:

The study was conducted in 200 individuals with normal hip joint of south Indian region attending Coimbatore medical college hospital. CT scanning of proximal femur was done and parameters measured. Patient name, age, sex, height and weight measured once the CT scan report of bony structure turn out to be normal. To assess the existing relationship between head and neck with femoral shaft by neck shaft angle, neck width, head diameter, acetabular angle of Sharp, horizontal offset, vertical offset, medullary canal diameter at the level of lesser trochanter and acetabular version parameters measured. These parameters tabulated and compared with western population and sexual and right and left side differences statistically analyzed.

RESULTS:

Our measurements showed a large difference on comparing with western population due to constitutional, racial and behavioral differences. High neck shaft angle measured in males comparing the females. Subtle yet significant differences noted in other parameters between sexes. Even differences noted in between sides.

CONCLUSION:

This study indicates a need for redesign of fracture implants and replacement prosthesis at hip. The obtained anthropometric femoral dimensions can be used to design and develop indigenous hip joint implants in India. The results of this study can also be used in forensic anthropometric studies.

INTRODUCTION

INTRODUCTION

Proximal femur in humans is a significant functional modification after man attained erect bipedal posture. The morphology of the proximal femur, specifically the relationship between proximal femur and shaft is an interesting subject in orthopedic literature. Critical evaluation of the proximal femur is still in infantile stage. Anthropometric analysis of the proximal femur has its own clinical importance, as the diagnosis and treatment and follow-up of pathologies arising from proximal femur like developmental dysplasia of the hip, slipped upper femoral epiphysis, osteoarthritis, fractures of the neck of femur and peritrochanteric fractures might benefit from greater understanding of this area. And it also helps in the pre-operative planning of fracture fixation, arthroplasty and osteotomy. So a thorough knowledge of proximal femur is a pre-requisite to understand the biomechanics of hip and planning for surgical procedures.

Fractures of around the hip and osteoarthritis of hip are relatively common in elders. Multiple epidemiological studies have identified the rising incidence of hip fractures and osteoarthritis of hip, which is not unexpected as the overall life expectancy of the people has increased over the period of time, due to high level healthcare and infection control. Most of the hip fractures occur in older age group due simple fall. In younger individuals, these are the result from high-energy trauma like road traffic accident or fall from height.

Surgical stabilization of hip fractures are done with the aim of obtaining rigid and stable anatomical fixation that would permit them to be independently mobile as early as possible. Osteoarthritis primarily treated with total hip replacement. Early mobilization is favored to prevent prolonged bedridden complications like pulmonary infections, deep vein thrombosis, bed sores, and generalized de-conditioning.

Common implants used in the proximal femur are DHS, DCS, AO cancellous screws, angle glide plates, proximal femoral nail and replacement arthroplasty prostheses. The standardized normal data of proximal femur geometry is available for western population. And this information had been utilized in prosthetic designing. And the very same implants designed for western population also used for Indian patients undergoing hip surgeries like internal fixation and replacement arthroplasties. Mean parameters of proximal femur morphometry for Indian population is lacking.

Constitutional and biomechanical behaviors of the Western population vary from Indian population. And structurally their bones are larger than the Indians. The usage of these over-sized implants adversely affects the functional outcome of the surgery by leading to multiple complications significantly. As internal fixation mandates drilling prior to implantation of AO screws and Dynamic Hip Screw, relatively large bone stock might be removed from the neck of femur to insert an implant which was designed for western population.

At present in total hip replacement surgeries, uncemented femoral stem components are used more often to avoid the complications of the bone cement. Uncemented femoral stem components require optimal contact to the proximal femoral cortical bone for an exact fit. This will reduce the micro-motion and provide primary stability then long-term stability can be achieved by trabecular bony ingrowths, as micro motion at the bone- implant interface hinders bony growth. Since body build, physique and daily habits markedly vary in different ethnic groups, it also becomes significant to design prosthesis to meet the daily needs of the people. The study is aimed to remove the lacuna of information of proximal femur geometry parameters in Indians by measuring neck shaft angle, neck width, head diameter, acetabular angle of Sharp, horizontal offset, vertical offset, medullary canal diameter at the level of lesser trochanter and acetabular version with Computerized Tomography in south Indian population.

AIMS AND OBJECTIVES

AIM OF THE STUDY

The aim of the study is analysis of the precise morphological parameters of the proximal femur by utilizing high resolution Computed Tomography imaging in living persons to analyze the various parameters of proximal femur geometry in south Indian population.

OBJECTIVES:

1. To assess the existing relationship between head and neck with femoral shaft by measuring neck shaft angle, neck width, head diameter, acetabular angle of Sharp, horizontal offset, vertical offset, medullary canal diameter at the level of lesser trochanter and acetabular version.

2. To analyze the differences between south Indian and western population to aid in designing suitable implant for Indian patients.

3. To analyze the differences in the measured parameters between male and females population to aid in designing suitable sex specific implant size for Indian patients.

4. To analyze the differences in the measured parameters between right and left sides.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Siwach et al (2003) in their study [3] analyzed 150 Indian cadaveric femurs both morphologically and radiologically using standardized techniques. They measured femoral head position, femoral neck offset, femoral head diameter, femoral neck diameter, extra cortical width at, 20 mm above and 20 mm below the lesser trochanter, angle of anteversion and neck shaft angle. They compared the parameters of Indian population with that of western and Chinese population. They found conventional implants designed for western population occupy more space while using it for Indians. They identified the mismatch in size, angle and orientation of implants, which may lead to complications like splintering and fractures.

Rawal et al (2012) in a study [4] analyzed 98 proximal femurs with Computed Tomography by measuring geometrical parameters the femoral head offset, femoral head center (HC), femoral head diameter, femoral head relative position, position of shaft isthmus, neck-shaft angle, bow angle, femoral neck length, canal flare index, femoral length, and canal width. They found 16.8 % difference in head offset between Indian and Swiss population. They found 10.4 % difference in neck shaft angle between Indian and Thai population. This can affect the mechanical stability of femoral stem. Mismatch in dimensions leads to micro motions and increase the chances of dislocation.

Saikia et al (2008) evaluated 184 proximal femurs of 104 individuals residing at northeast region of India with Computed Tomography [5]. They measured the Center edge angle, joint space width, acetabular depth, femoral neck anteversion, acetabular version and neck shaft angle in both sides and both sexes. They identified significant difference in mean neck shaft angle, acetabular angle and acetabular version of Northeastern people while comparing with western literature. They also noted that the values were lower on the right side than the left side. They concluded awareness of the average dimensions of the proximal femur will assist to design a suitable prosthesis for Asians.

Toogood et al (2009) analyzed 375 adult femur specimens with digital photographs [6]. They measured neck shaft angle, Neck version, Alpha angle, Beta angle, Gamma angle, Delta angle, anterior offset, posterior offset, superior offset, inferior offset, antero posterior physeal angle and Lateral physeal angle in both sexes. They observed neck shaft angle in Indians as 129.23 deg in contrast with Hoagland and Low's 135 deg. They observed differences between male and females and between those aged more than 50 years and younger people. They stated that this will impact the outcome of surgical procedures when this variability is not taken into consideration.

Ravichandran et al (2003) studied neck shaft angle, length and width of neck of femur [7] in 578 unpaired femora of south Indians. They demonstrated Indian dimensions obviously lesser than western standards. They observed neck shaft angle as 126.55 deg and neck width as 30.99 mm in south Indians. Constitutional and biomechanical factors differ in Indians comparing westerns. And they suggested the biomechanical engineers to alter the implant designs specifically for Indians.

Filiz Elbuken et al (2012) retrospectively analyzed 18,943 individuals aged 20 to 108 years with dual energy absorptiometry [8] images. They observed significant difference in neck shaft angle between the various age groups and statistically significant minor difference between males and females. The mean neck shaft angle is greater in males than females.

Jing guang et al (2004) in a study, X ray and dual energy x ray absorptiometry were used to obtain the femoral neck angle on both sides of 76 normal participants and the healthy side of 20 patients with femoral neck fractures [9]. They analyzed variation in neck shaft angle caused variation in stress levels. With 125 – 120 deg a sharp rise in stress was identified. They identified variation in neck shaft angle in right and left side in the same patient. They also observed some subjects had a more than 10 degree difference between left and right femoral necks.

Nelson et al (2000) studied the proximal femurs in 371 postmenopausal white and black women with Dual Energy X ray Absorbtiometry scan [10]. They measured neck shaft angle, Neck and shaft length, cross sectional geometry and bone marrow density. They concluded that differences do exist in bone strength, cross sectional geometry and bone mass in the neck of femur of white and black postmenopausal women.

Anderson et al (1998) in a study, femoral neck shaft angles were measured in 30 modern, historic and pre historic skeletal remains [11]. They compared their measurements with various populations with varying economic levels. They showed that there is a strong correlation exists between neck shaft angle and economic levels. It reflects the effects of differential cultural and habitual levels during human development on neck shaft angle. They also analyzed sexual and bilateral differences and concluded sexual differences are not consistent and individual asymmetry is not uncommon.

Rubin et al (1992) analyzed the in vitro accuracy of 32 proximal femur measurements using radiographs and Computed Tomography scans. They compared them with the parameters derived from the anatomical dimensions [12]. Routine radiographs provide only a rough approximation (mean difference 2.4 +/- 1.4 mm). CT scans can provide better accuracy (mean difference: 0.8 +/- 0.7 mm). They concluded that CT scan is a precise technique for planning of proximal femur surgeries. They also recommended the use of custom made prosthesis.

Olav Reikeras et al (1982) in a study determined neck shaft angle in 48 pairs of femur specimens from of elderly Norwegian cadavers [13]. And the neck shaft angle is 120 - 135.5 deg by radiographic measurements. In their study there was no significant sexual or bilateral difference. He also stated that there was an age-linked decrease in neck shaft angle to values of 126 -132 deg in the adult.

Michael et al (1995) analyzed 193 peritrochanteric fractures of hip with failure of fixation [14]. Along with other variables they found out that use of high angle sliding hip screw device (150 deg) were also associated with a higher risk of implant failure.

James et al (2000) et al studied the proximal femoral anthropometry in 35 persons using quantitative CT scan [15]. They stated that three dimensional analysis of the proximal femoral anatomy has significant importance in understanding the biomechanics of hip joint. Every patient has heredity, constitutional and developmental factors that determine his proximal femoral bone density, bone shape and biomechanical integrity.

Khang et al (2003) investigated the anatomic differences between femurs of Korean with Americans and Japanese [16] and they suggested specifically designed hip prosthesis for Korean and Asian patients in contrast to Americans.

Siwach et al (2007) stated that in total hip replacement, it is mandatory that the dimensions and design of femoral stem should match the anatomy of proximal femur [17].

Reddy et al (1999) stated that due to oversized femoral components in THR surgeries, complications like anterior thigh pain, aseptic loosening, intraoperative splintering and fractures are common in Indian population [19].

Nurzenski et al (2007) found out that lifestyle factors can influence the geometric indices of bone strength in proximal femur [20].

Mishra et al (2009) studied [18] proximal femur geometry both morphologically and radio graphically in 25 pairs of cadavers in Nepal. They measured femoral head and neck diameter, proximal femoral diameter, neck shaft angle, medullary canal diameter at above and below lesser trochanter, extra cortical and endosteal width. They found that the measurements where different on comparing with Caucasians. He concluded that implants designed for western people should be used judiciously. And designing of fracture implant should be specific for south Asian population to avoid mismatch complications like non union and avascular necrosis.

Aasis et al [26] studied 200 cadaveric femora in individuals less than 40 years of age by digital photographs. Femoral head diameter, absolute horizontal and vertical offset, neck inclination and Neck shaft angle were measured. Between males and females, they found small, yet statistically significant differences, in absolute horizontal and vertical offset, neck inclination and neck-shaft angle. Males tended to have a higher neck-shaft angle and low neck inclination. No correlation was found between horizontal and vertical offset.

While standardizing the offset distances with femoral head diameter, the horizontal offset ratio was lower in male femoral specimens.

Panula et al (2008) retrospectively analyzed [40] geometrical differences in occurrence of trochanteric and neck of femur fractures by measuring femoral neck axis length and neck shaft angle. They concluded that neck shaft angle has relation with loading of hip with stress. He found the neck shaft angle values are higher for men than women.

Humphry (1889) noted [36] that there is an inverse relationship exists between the neck-shaft angle and biomechanical loading levels of hip joint. Neck-shaft angles are particularly high (around 150°) in intrauterine and in newborn period and then gradually the angle decreases during development.

Houston & Zaleski (1967) in their study [37] demonstrated that, even in immature persons, during growth there is a correlation exists with lowering of neck-shaft angle with physical activity levels. During maturation greater decrease in femoral neck-shaft angle seen in persons with higher activity levels, from the greater neonatal value to the lower adult value.

Radin & Paul in a study [38] states that from an adaptive perspective, when the femoral neck is in a more varus orientation or lower the neck-shaft angle, tends to reduce the moment at the hip joint. Hence this forms a highly stable hip joint, especially during the first year of life; when proximal femur is not much affected by the loading of hip.

Travison et al analyzed [39] proximal femur geometry by Dual X-ray absorptiometry in 1,190 white, black and Hispanic men. They measured the narrow neck, intertrochanter and shaft regions of the proximal femur by hip structural analysis. They found differences between anthropometric parameters between races.

Gaurav et al (2012) analyzed [41] customized femoral stems in dynamic conditions like slow walk, normal walk, fast walk, upstair, downstair, standing up and down, standing on 2-1-2 legs, knee bend and jogging. And they concluded that lesser stresses in head and neck regions of customized femoral stem than the standard implant. They suggested customized feasible designs for the Indian population to reduce stress load on the implant.

Adam et al analyzed [47] 30 human cadaveric femurs with Computed Tomography to develop new prosthetic implants with computer aided designing. They concluded that CT is a precise technique to study anatomical details.

Irdesel and Ari studied [48] proximal femoral geometry using radiographs in 190 Turkish women. They measured femoral neck shaft angle, femoral neck width, intertrochanteric width, femoral neck axis length and hip axis length.

They analyzed the relationship of the parameters with body mass index and concluded that correlation between these parameters and body mass index existed.

Taner and Khalil analyzed [49] the differences in proximal femoral anthropometry in two different ages of Anatolian population groups by using 36 cadaveric femora. They measured neck shaft angle, maximum length, trochanter length, proximal breadth, vertical and horizontal diameter of head, vertical and horizontal diameter of neck, midshaft circumference, midshaft antero-posterior and transverse diameter and distal breadth. On statistical analysis showed significant difference between two ages of population and right and left sides.

ANATOMY OF THE HIP JOINT:

The hip is a classical, multi-axial ball and socket type of joint. It meets all the four characteristic features of a synovial joint: it has a joint cavity; articular cartilage covers the joint surface; it contains synovial fluid and a ligamentous capsule surrounds the articular surface. The acetabulum is cup shaped and formed by the innominate bone with contributions from the ischium (40%), the ilium (40%) and the pubis (20%). The triradiate cartilage separates these bones in the skeletally immature person and fusion starts at the age of 14 to 16 years and is usually complete by the age of 22 to 23 years. Fibro cartilaginous labrum is attached with the acetabular rim. The articular surface of acetabulum is an incomplete ring. As the pressure of the body weight falls in erect posture, the cartilage is broader and thicker above. Below opposite to the acetabular notch it is deficient. The acetabular fosse is devoid of cartilage, but it contains fibro-elastic fat largely covered by synovial membrane.

The proximal femur comprises of the head, neck, a greater trochanter and a lesser trochanter. The femoral head articulates with the acetabulum. Both the articular surfaces are curved reciprocally and are neither co-existence nor completely congruent. A corresponding articular cartilage covers the femoral head. Centrally the cartilage is thickest. The covered region forms 60 to 70% of sphere. The fovea capitis is an area on the center of the femoral head not covered with cartilage, where ligamentum teres inserts. It provides blood supply but does not take part in providing stability to the joint. It is intra-articular, but it is actually extra-synovial.

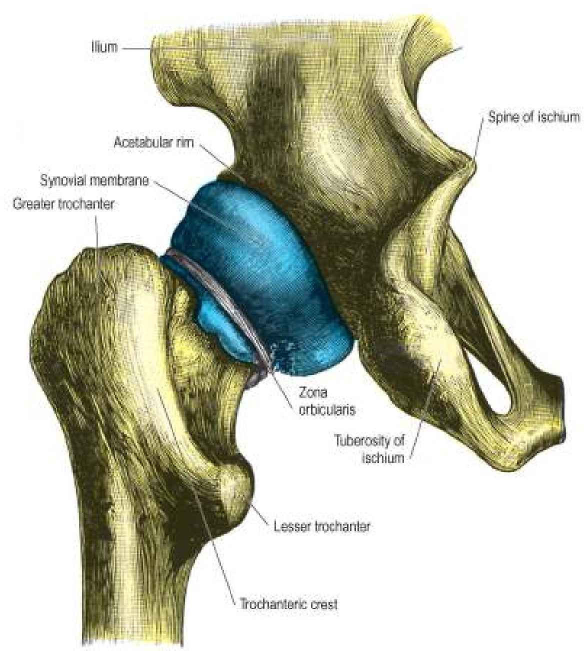
The femoral head is attached to the femoral shaft by the neck. Roughly femoral neck is pyramidal in shape, flattened anteriorly and at its junction of the shaft is marked by a prominent rough ridge termed the intertrochanteric line. A rounded ridge termed the intertrochanteric crest, which joins the posterior aspect of the greater trochanter to the lesser trochanter, marks the posterior surface at its junction with the shaft. On the upper part of the crest, there is a rounded protuberance called the quadrate tubercle. Femoral neck length varies upon body size. The neck forms an angle with the shaft which is usually 135±7° in the normal adult. The neck-shaft angle is 150° at birth steadily decreases to reach 125° in the adult, due to bony remodeling in response to changes occurring in loading patterns. The femoral neck in coronal plane is also anteriorly rotated. This rotation of femur is described as femoral anteversion. The angle of anteversion is measured between a mediolateral line drawn through the femoral condyles and a line through the femoral neck and head. The normal range is 15 to 20°.

The **greater trochanter** is a large quadrangular projection, laterally positioned at the junction of the neck with shaft. Its medial surface presents a roughened depressed area, the trochanteric fossa. Most of the gluteal muscles are inserted on the greater trochanter.

The **lesser trochanter** is conically shaped, projects medially off the postero medial surface of the femur and gives attachment to the psoas major at its summit, and iliacus at its base. The upper fibers of adductor magnus insert on its posterior surface.

The joint is covered by a capsule, made up of outer longitudinal and inner circular fibers. Rich synovial anastomoses occur at the margins of the articular cartilage.

HIP JOINT WITH PROXIMAL FEMUR

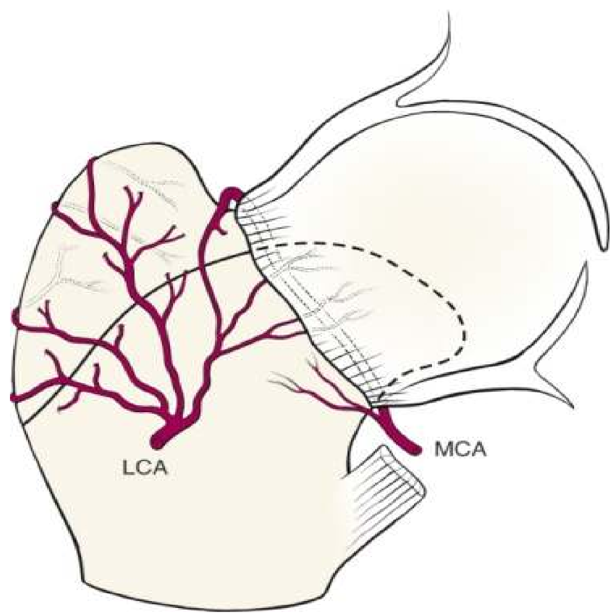


HIP JOINT WITH CAPSULE

VASCULAR SUPPLY:

Vascular supply to the femoral head arises from three sources. Medial and lateral circumflex arteries are two major branches of the profunda femoris artery. They further divided into ascending, descending and transverse branches. Third and small contribution arises from a vessel found within the ligamentum teres (present in 80% of the population) most commonly a branch from obturator artery.

Vascular supply of proximal femur



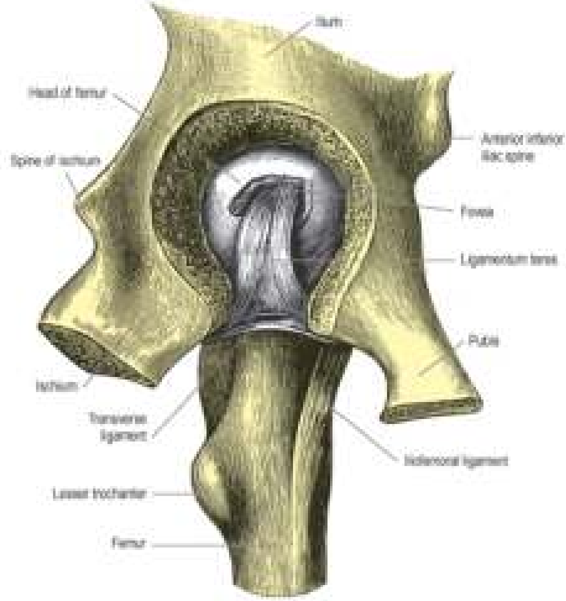
LIGAMENTS

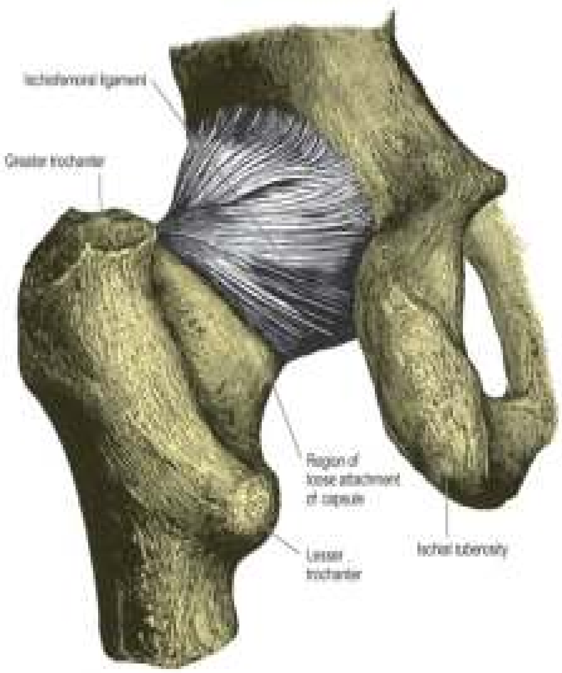
Inverted ‘Y’ or a modified ‘?’ shaped iliofemoral ligament seen at anterior aspect of hip. It attached proximally from the ilium to insert on the intertrochanteric line in a spiralling fashion. It is relaxed in flexion and taught in extension and to keep the pelvis from tilting posteriorly in upright stance and limiting the adduction of the extended lower limb. It is the strongest ligament in the body with a tensile strength greater than 350N [21]. Strength of anteroinferior portion of capsule is contributed by the pubofemoral ligament which is the weakest among the four ligaments. Posteriorly the joint is stabilized by ischiofemoral ligament, medially it inserts on ischium and laterally on superolateral aspect of the femoral neck. In the hip joint two further ligaments present and plays little role in providing stability. One, the ligamentum teres and it can be torn in traumatic dislocations. The second, zona orbicularis or angular ligament, like a button hole it encircles the femoral neck.

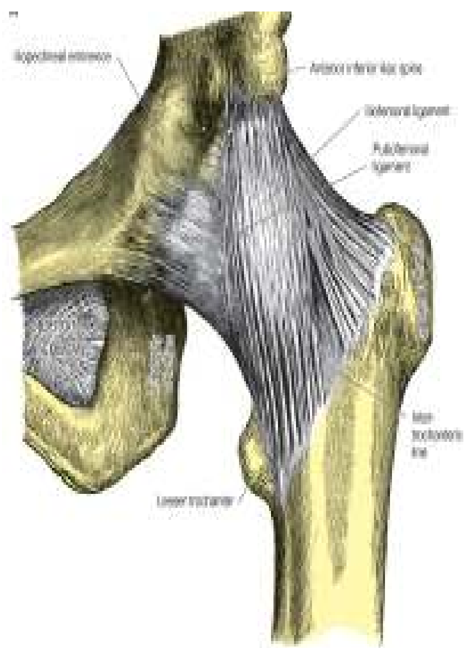
NEURAL ANATOMY

Articular braches arising from obturator nerve supply anteromedial aspect of the joint. Branches of the femoral nerve contributes to the anterior aspect. Articular branches of sciatic nerve, superior gluteal nerve and nerves to quadratus femoris contributes to the posterior aspect.

LIGAMENTS OF HIP







Musculature of proximal femur:

A fibrous layer, the fascia lata invests the musculature of the hip and thigh. It continuously surrounds the thigh. It is attached proximally to the body of the pubis, pubic tubercle, the inguinal ligament, lip of the iliac crest, posterior aspect of the sacrum, and ischial tuberosity. Its stiff and inelastic, thus limits bulging of the thigh muscles to improve the efficacy of their contractions.

Iliopsoas is the major flexor of the hip joint. This comprises iliacus, psoas major and minor. Psoas major originates from vertebral bodies of T 12 to L 5 and inserts into the lesser trochanter. It is joined with iliacus muscle at the level of the inguinal ligament to form the iliopsoas.

The largest and most powerful extensor of the hip is **gluteus maximus**. It is also the most superficial.

The **gluteus minimus** is inserted in to the rough impression on its anterior surface.

Gluteus medius is inserted into the oblique strip, which runs downwards and forwards across its lateral surface.

Pyriformis is inserted into the upper border of the trochanter.

Obturator internus, gemelli superior and inferior are inserted by a common tendon into the medial surface of the upper border of the trochanter.

Obturator externus is inserted into the trochanteric fossa.

CALCAR FEMORALE:

According to Harty and Griffin (1957), the calcar femorale is a dense vertical bone, extending from the postero medial portion of the upper femoral shaft under the lesser trochanter to reach the posterior aspect of the neck medially and to blend into the spongy bone of the greater trochanter laterally. It represents upward elongation of the diaphyseal cortex into the inferior part of the neck through the lesser trochanter. Intactness of calcar is necessary for supporting the prosthesis, absence of which results in sinking of prosthesis.

BIOMECHANICS OF HIP

The hip joint is unique developmentally, anatomically and physiologically; and therefore greater understanding of hip biomechanics is essential. The hip is a true ball-and-socket joint while exhibiting remarkable stability, enabling a greater range of motion in multiple planes. 2/3 of body weight is supported by femoral heads. Hip joints act as the structural link between the axial skeleton and the lower extremities. They carry forces from the head and neck, trunk and upper extremities to the ground and transmit forces vice versa [22]. Hip joint is exposed to greater than normal forces in athletic activities.

Recent advances in hip biomechanics led to the precise evaluation of joint function, better development of therapeutic programs for of joint disorders, better understanding in planning and performing reconstructive surgeries procedures and implant designing [23]. Better understanding of the mechanism of injury is also made possible by the biomechanical principles.

Basic analysis of balancing forces and moment arms in the hip joint can be used in estimating the effects of alterations in joint morphometry and hip joint reaction force [23] .With a simplified, two-dimensional analysis, static loading of the hip joint has been studied.

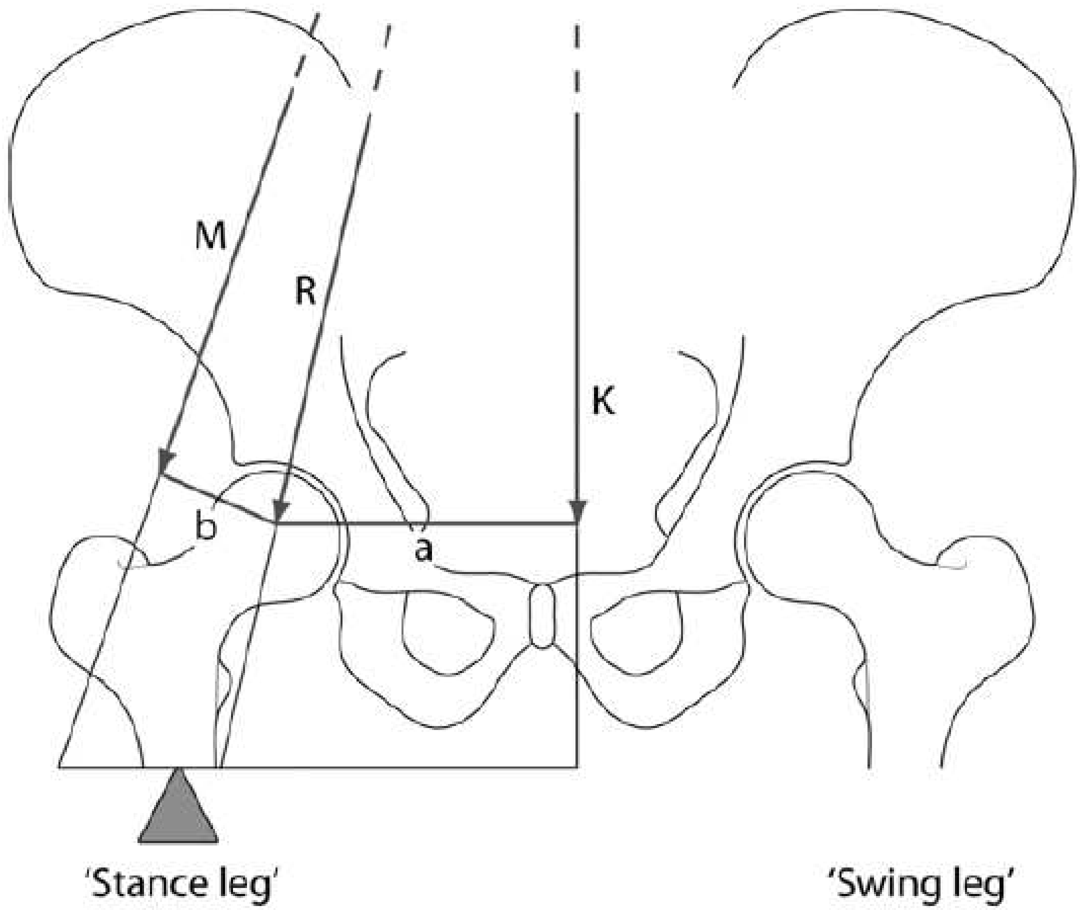


Diagram for calculating hip joint reaction force on single leg stance

K – Whole body weight minus weight bearing leg

M – Combined force of abductor muscles

R – Joint reaction force

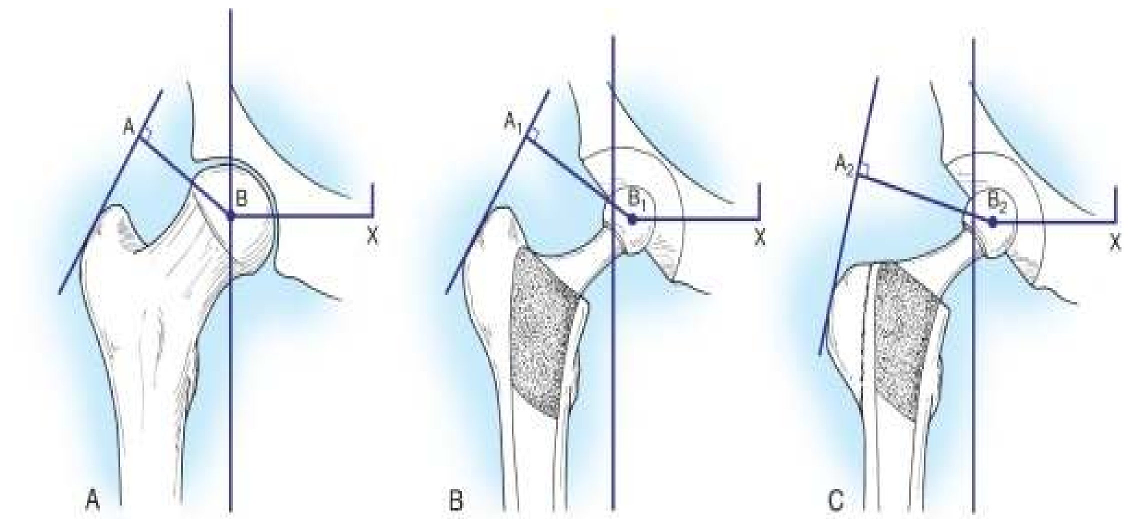
a - moment arm of body weight

b - Moment arm of abductor muscle

While standing on both legs, weight of the body acts equally on both hips and center of gravity lies equidistant from the centre of femoral heads. And this force is equal to body weight minus the total weight of both legs which is supported equally by the femoral heads. Hence the resulting two vectors are vertical.

When a person stands on his single leg, the non-supporting leg is now calculated as part of the body mass. This weight is acting on the weight-bearing hip. So the resulting new centre of gravity moves distally and far away from the supporting leg. This force exerts a downward motion on the centre of the femoral head. This moment is created by the body weight ***K***, and the moment arm is ***a*** (distance from the centre of gravity to femoral head). The combined abductor muscles resist this movement by moment ***M***, and the moment arm is b. The abductors of hip include gluteus medius and minimus, the tensor fascia lata, the upper fibers of the gluteus maximus, and the obturator internus and Pyriformis.

But this abductor moment arm b is shorter than the lever arm of the body weight a. Hence the abductor muscles force should be multiple times of body weight. Magnitude of these forces depends upon the lever arm ratio, which is the ratio between the body weight moment arm (a) and the abductor muscle (b) moment arm (***a:b***) [24].



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Lever arms acting on native hip joint and with total hip replacement

A - Moment produced by weight of the body applied at the body's center of gravity X, body weight lever arm B-X, abductors moment A, acts on shorter lever arm A-B.

B - in **THR** high offset neck lengthens lever arm A-B, deepening of acetabulum shortens lever arm B-X,

C - Distal and lateral reattachment of osteotomized greater trochanter lengthens lever arm A-B.

The abductor muscle force levels for single leg stance are critically three times of bodyweight, corresponding to a level ratio of 2.5. Therefore whenever there is an increase in the lever arm ratio, it also increases the abductor muscle force to compensate body weight which is required for maintenance of gait. This also increase the force acts on the head of the femur.

When other things are being equal, higher hip forces are seen in persons with short femoral necks and significantly in persons with wider pelvis. Naturally to accommodate a birth canal, women have wider pelvis hence higher forces act at hip than men [25]. This may be the reason for relatively higher incidence of hip fractures and replacements in women than actually men do.

Effective reduction in the joint reaction force can be utilized in the management of painful hip disorders. This can be achieved by improving the abductor force or its moment arm or by reducing the body weight or its moment arm.

Better understanding of biomechanics is a crucial step in analysis of cultural behavior on geometry and implant designing to assess the various patterns of stress loading.

Hip fractures

Fractures of the proximal femur involving the neck and trochanters are quite common. Hip fractures contribute to 20% of orthopaedic workload. Lifetime risk of sustaining hip fracture is 40- 50 % for women and 13 to 22% for men. In 1997 Gullberg et al estimated that the future incidence of hip fracture worldwide would double to 26 lakhs by 2025, and 45 lakhs by 2050[1]. 26% of all hip fractures occurred in Asia in 1990, whereas this incidence could rise to 37% in 2025 and 45% in 2050 [2]. The percentage increase will be greater in men than women. These fractures are associated with substantial morbidity and mortality; 30% of elderly patients die within 1 year of sustaining the fracture.

As the standard of living and health care facility have improved the life expectancy of people, the lifetime risk of sustaining osteoporotic hip fractures have been increased. The lifetime risk for a vertebral, hip or wrist fracture has been estimated to be 30% to 40% in developed countries. Osteoporosis is one of the major public health related problems in developed countries. According to World Health Organization, osteoporosis is second only to cardiovascular disease as a leading health care problem. Most severe of its outcome, fracture of the neck and trochanter, is the main cause of osteoporosis related mortality and morbidity [1]. Candidate risk factors include age more than 60 years, female sex, steroid use, smoking, excess alcohol consumption, family history, prior fragility fracture and high Body Mass Index and low femoral neck Bone Mineral Density.

Although caused by multiple factors, [2] hip fractures are the ultimate result of mismatch between forces acting on the bone and its strength. As the person ages associated with osteoporosis, the “champagne flute” shape of the metaphyseal canal becomes tubular with atrophy of internal bony structure.

Internal fixation of these fractures with implants is mandatory for early mobilization and rehabilitation of the patients to prevent the prolonged bedridden complications like venous thrombosis, pulmonary complications, pressure sores, urinary tract infections and generalized malnourishment. Successful surgical treatment of hip fractures is entirely dependent on restoration of the neck-shaft angle and prevention of shortening.

The common implants used for the surgical treatment of proximal femoral fractures include

(i) Dynamic Hip Screws (DHS)

(ii) AO Cancellous screws

(iii) Proximal femoral nail and

(iv) Hip replacement arthroplasty prostheses.

DHS used for surgical stabilization of stable intertrochanteric fractures. For unstable fractures proximal femoral nailing is used.

AO screws are used for undisplaced and valgus impacted fractures and in displaced fractures of neck of femur when the patient's physiological age is less than 65 years. Cemented bipolar hemiarthroplasty is the treatment of choice in patients with minimal household ambulatory, more than 75 years of age with displaced femoral neck fractures. Patients with pre-existing arthritis are advised to undergo total hip replacement as a single surgical procedure.

These implants are designed primarily for use in Western population by the anthropometric measurements obtained from them. In the market various sizes in length of these implants are made available. But other factors such as thread diameter etc are not considered while using it in Indian population.

IMPLANT DIMENSIONS

A) DHS

DHS with barrel plate used for trochanteric fractures

	DIMENSION
Thread diameter	12.5mm
Thread length	22 mm
Shaft diameter	8 mm
Barrel length	Std – 38 mm Short – 25 mm
Barrel width	19 mm
Angle	125 deg to 150 deg

AO screws

Proximal femoral nail

B) AO screws

Thread diameter	6.5 mm
Shaft diameter	4.5 mm

C) Proximal femoral nail

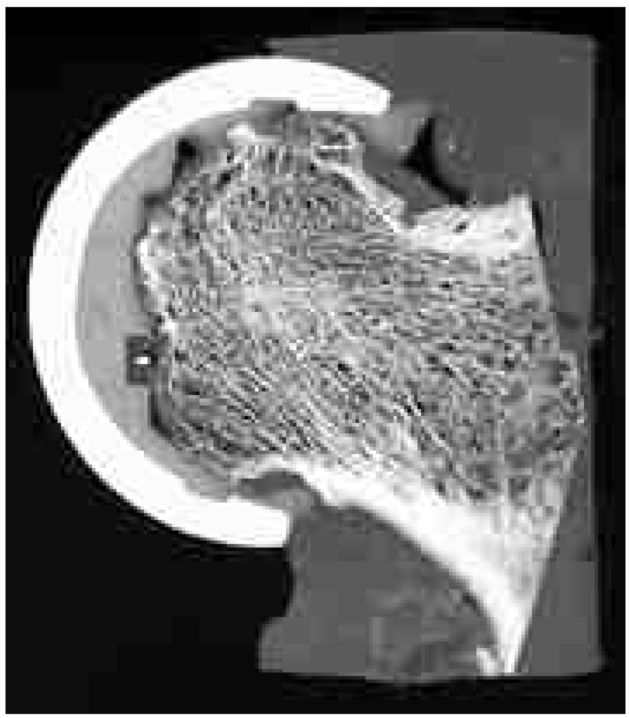
Nail length	24 & 38 mm
Nail diameter	10, 11, 12mm
Angle between proximal & distal part	6 deg
Neck screw diameter	8 mm
Anti- rotation screw diameter	6.5 mm
CCD angle	130 and 135 deg

And even constitutional and biomechanical factors of western population vary from those of Indian population. Hence the commercially available implants may not be the optimal fit to patients of Indian origin because of the anthropometric variations is not considered in implant designing.

The usage of these large sized implants may adversely affects the end result of surgical fixation by leading to higher incidence of avascular necrosis, malunion and nonunion.

EVALUTION IN REPLACEMENT ARTHROPLASTY

In 1923, by Smith-Petersen a young surgeon introduced the concept of **mould arthroplasty** by exposing the bleeding cancellous bone of acetabulum and femoral head. With gentle motion metaplasia of fibrin to fibro cartilage occurs. Later he used glass in place of femoral head. Even though the initial results were encouraging, glass was broken within months.



Surface arthroplasty

After many years of research the solid ideal material proposed by Dr. Venable in 1936. That alloy is **Chromium-Cobalt-Molybdenum** for the orthopedic applications. He calls it as **Vitalium**.

Austin Moore (1950) designed prosthesis with the metal head connected with the stem which was driven into the medullary canal of the femur. Since this the concept of near total of the femoral implants emerged. And he utilized posterior access to hip joint for femoral head fractures which was famously called as "**way of Moore**" or "the access of the South".

Austin Moore prosthesis

Thompson (1952) started using a model resembling the prosthesis of Moore. But it had no window. Unlike Moore prosthesis it did not need bony ingrowths into the window for secondary stabilization.

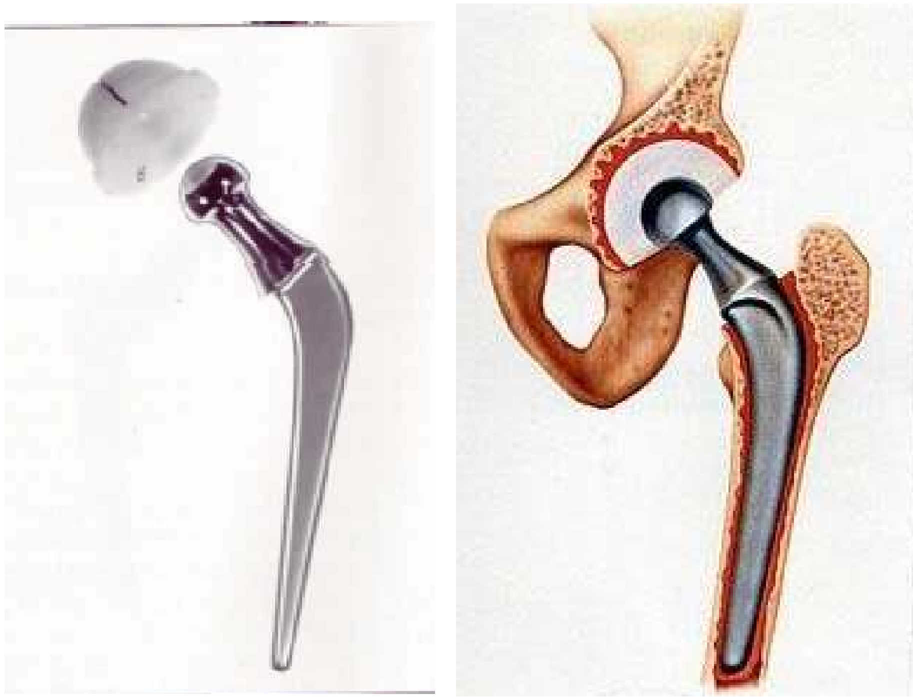
Thompson prosthesis

For the first time in 1951 **Mac Kee** used Vitalium in his total hip prostheses. Loosening seen with stainless steel is not seen with this material. He used to fix the acetabular cup with large posterior screws.

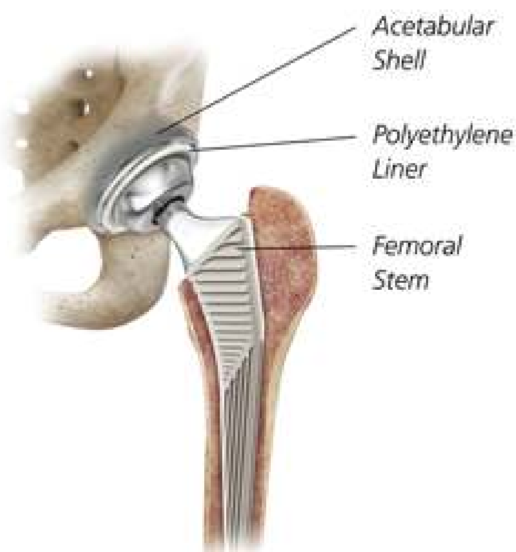
The **professor John Charnley** (1960) did pioneering work in various aspects of replacement arthroplasty including biomechanics, implant material, design, and low frictional arthroplasty. He used polytetrafluoroethylene or **Teflon** in the place of cartilage, which failed in few months.

Teflon replacing cartilage

He was the first one to **use bone cement** (polymethylmethacrylate) in fixation of components to prevent the loosening of femoral stems. And he utilized plastic acetabular cups for total hip replacement. To prevent the complication of posterior subluxuation aroused due to the usage of small femoral heads he advised lateral approach with trochanteric osteotomy to tighten the glutei muscles.



CEMENTED TOTAL HIP REPLACEMET



UNCEMENTED TOTAL HIP REPLACEMENT

P. Boutin (1970) utilized the concept of using **Ceramics** for their quality in low friction and biocompatibility which allows macro-anchoring. In his total hip prosthesis acetabular cup is made of ceramics and the femoral part had two parts: a ceramic head fixed on a steel body.

Ceramic on ceramic

BIPOLAR STEMS

The biological component is the self-locking action while the mechanical component is represented by 3 point fixation in the femoral shaft.

Preservation of the acetabulum

It is postulated that shear forces distributed between the outer and inner bearings will preserve the acetabular surface from wear and tear.

1. Wear of acetabulum is diminished through reduction of total amount of motion that occurs between the acetabulum and metallic outer shell.
2. By the interposition of a second low-friction interface in between metallic shells.

The Bipolar prosthesis was first introduced by JAMES. E. BATEMAN and GILIBERTY in 1974. The commonly known versions of Bipolar prosthesis are Monkduo pleet, Monk (1976), Hastings Bipolar prosthesis, Devas et al (1983), Modular Bipolar prosthesis (Biotechnic, France) and Talwalkar's Bipolar endoprosthesis (Inor, India).

Bipolar hip prosthesis has the great advantage of a second joint below the acetabulum, it has an outer head of metal which articulates with the acetabulum and a second metallic head which articulates with the high density polyethylene

(HDPE), lining on the inner surface of the outer head. This prosthesis proved to be very useful and results were encouraging.

***Self-centring action*:**

The positive eccentricity of the centres of rotation corrects alignment.

***Range of Motion*:**

Because of compound bearing surface, bipolar designs offer greater overall range of motion than either unipolar femoral stem designs or conventional THR.

The available range of prosthesis:

- Sizes (dia.37-53mm, in 2 mm increments).
- Outer shell made of stainless steel 3.16 L.
- Insert made of UHMWPE.
- To accept metal or ceramic femoral heads.
- Sterilized by Gamma irradiation.

Recent modifications in bipolar stems:

Axis of the metallic and polyethylene cups are now placed eccentric so on loading of hip, metallic cup rotates laterally than medially. This avoid varus fixation and impingement of head on the cup, fractures of poly bearing insert and dislocation are avoided.

TOTAL HIP REPLACEMENT

When Charnley first invented and used bone cement it became a common procedure to use it in all hip replacement procedures. Aseptic loosening of the femoral stem in cemented arthroplasty is one of the main complications on long-term follow-up. And other complications are improper load distribution and discomfort when anatomical parameters are not restored. This led to the development of implants with biological fixation. These uncemented femoral stems need exact contact to the supporting cortical bone to obtain primary stability by reducing micro motions at the bone prosthesis interface. They obtain long term stability by trabecular bony ingrowths in the porous outer surface over a period of time. These uncemented femoral stems are used more often to avoid the disadvantages of bone cement and because of the ease of implantation.

Aim of total hip replacement is to create a stable joint with an optimized range of motion. Femoral medullary cavity does not have a uniform shape and significant variations in endosteal anatomy have been described. Straight stems which disregard the differences between right and left are used at present. An ideal cementless stem can be described as a stem which can transfer the loads to large surface area of the bone enough to minimize stress and motion at the bone implant interface. Optimal fixation of the implant allows physiological load transfer. It can be achieved with an anatomically oriented femoral stem.

Stability of the femoral component depends upon the balance of proximal and distal load transfer from the prosthesis to the bone. But if the medullary canal widens with increasing age, medial migration of the implant may occur, which may leads to mechanical loosening and sinkage of the prosthesis.

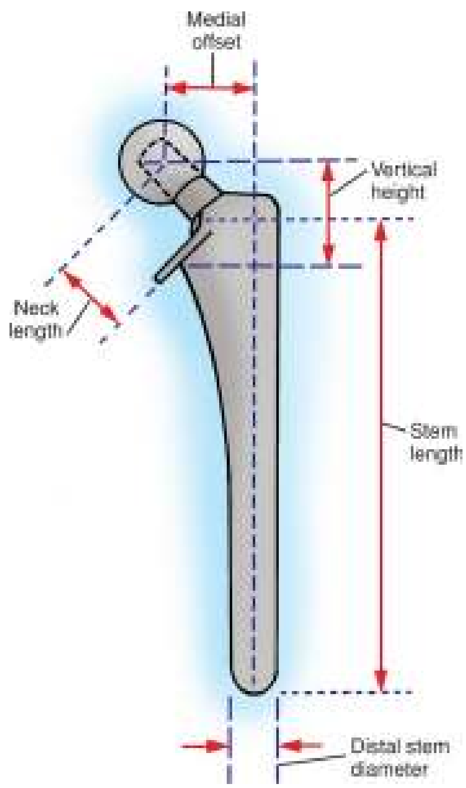
If the implant is too large, the femur can fracture as it is driven inside the bone, so the tendency is to undersize for safety is higher. But if the implant is highly undersized, it may sink into the medullary cavity and leg length is not achieved. There is a high chance of bonding of bone with implant. So, the correct implant size is very important. Proper sizing of the prosthetic components are crucial to the success of a total hip arthroplasty. This can be achieved by preoperative templating. In total hip replacement failure to restore adequate hip offset can compromise the biomechanics of muscular efficiency of abductors, and limb length. Therefore this will influence the long-term surgical outcome and patient's function. A person with low neck shaft angle tends to have higher horizontal offset, and with a higher neck shaft angle tends to have lower horizontal offset.

The prime function of the femoral stem is the replacing the femoral head and neck after resection of the arthritic segment. The ultimate goal of THR is accomplishment of a biomechanically sound, stable hip joint. This is achieved by restoration of the normal center of rotation of the femoral head which is determined by three factors.

(1) medial offset (horizontal offset)

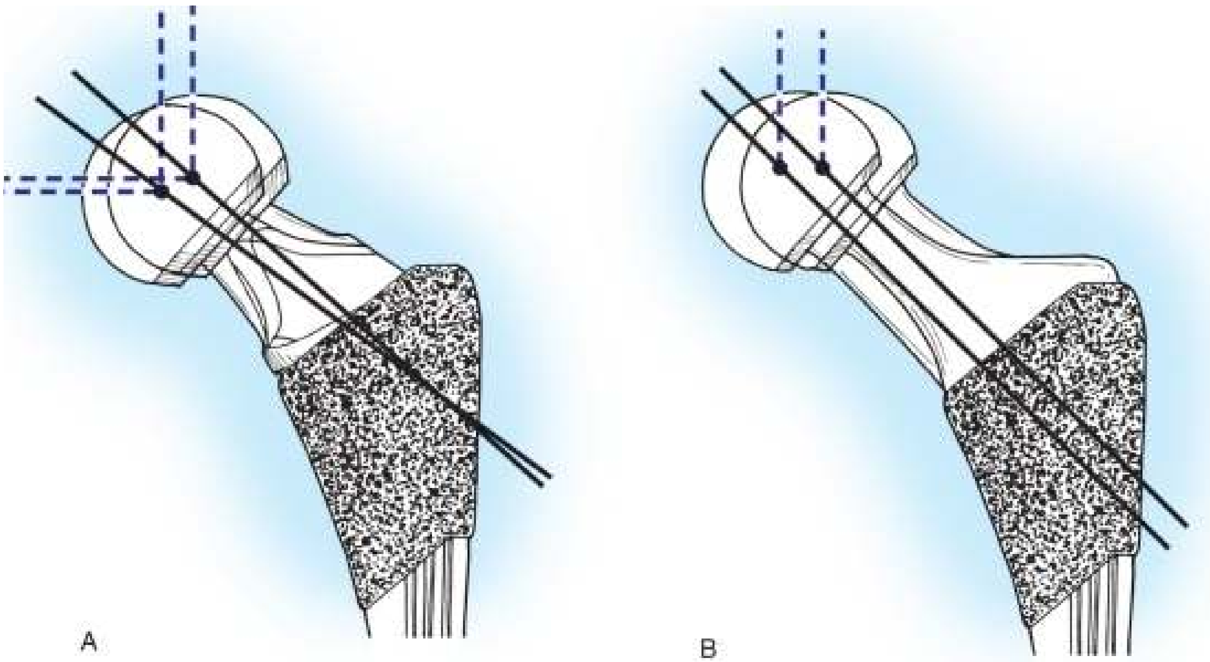
(2) vertical height (vertical offset)

(3) version of the femoral neck (anterior offset)



Femoral stem showing horizontal and vertical offsets

Horizontal offset is the horizontal distance from the femoral head centre to a line passing through the axis of the stem. It is primarily a function of stem design. Inadequate restoration of offset shortens the abductor moment arm and causes increased joint reaction force and leads to dislocation, bony impingement and limp.



Femoral neck variations to increase horizontal offset.

A - Reduction in neck stem angle.

B - More medial positioning of neck on stem.

Vertical offset or vertical height is determined by the length gained by the modular head and the base length of the prosthetic neck. The diameter of femoral canal alters vertical height by changing the depth of the implant inserted into it. Hence depth of insertion is determined primarily by the fit of implant within the femoral endosteal canal.

Anteversion refers to the anterior orientation of the femoral neck in reference to the coronal plane. Restoring the neck version is important to achieve stability in THR. The normal anteversion is 10 to 15 degrees. Correct neck version is achieved by rotating the femoral stem within the canal. In uncemented THR femoral stem must be inserted in the same plane as the femoral neck to achieve exact fit to the proximal femur. This will accomplish primary rotational stability.

Templating with radiographs provide only a rough approximation to the real size and shape of the THR components which will fit most precisely. Preoperative radiographic assessment could not be done in some patients with advanced osteoarthritis due to inability to internally rotate their hips. Most accurate determination of the size of prosthesis must be done during the surgical procedure.

THR IMPLANTS

THR components are entirely different from fracture implants as they should withstand many years of cyclical loading which is equal to 3 to 5 times of bodyweight, and during running and fast walking they can be subjected to overloads of 10 to 12 times of body weight.

The abductor lever arm is shortened in advanced arthritis and other hip pathologies due to loss of the femoral head. Aim of the total hip replacement is surgical correction of the lengths of the two lever arms of hip to make their ratio to approach 1: 1, as this can theoretically reduces the load on the hip joint by 30%.

Stress shielding by the implant causes adaptive bone remodeling which compromises implant support. This produces loosening, and increase the risk of fracture of the femur or the implant itself. Metal backing is required, when uncemented acetabular fixation is used. Ideally, the metal should contact wide area of the acetabular subchondral bone to augment biological fixation and to prevent stress concentration. Elastic coiling of the bone stabilizes the implant.

Design changes helps in improving available motion

By using large sized head with trapezoidal neck the range of available motion has increased. Impingement also reduced. This can be utilized in improving range of joint motion in Indians for their life style.

THR COMPONENTS SPECIFICATIONS

(IN IMAGES SYNERGY UNCEMENTED SYSTEM USED)

Femoral Stem:

Femoral stem (TITANIUM)

Available sizes 9 – 18 (135 – 180 mm)

Neck angle – 131 deg

Available with made up of (CoCr) cobalt chromium alloy or titanium.

circumferential surface finishes: 1) porous-coated, 2) HA-coated,

3) Porous plus HA (hydroxyappatite) and 4) a grit blasted

Femoral head:

Available sizes -3, +0, +4, +8, +12, +16.

Made up of (CoCr) or OXINIUM

Femoral head

Acetabular interfit cups:

Sizes 42 – 68.

Porous coated

Acetabular cup

Acetabular Liners XLPE:

Sizes 42 – 76

Made of extensively linked polyethylene

Sterilized by Gamma radiation

Acetabular liner (REFLECTION)

Differences in anatomical parameters

Even though various sizes of these implants do exist, the usage of these over-sized implants may adversely affects the functional end result of the surgery in Indian population. Hence individual anatomic variation might have taken into consideration. To our knowledge references about the proximal femoral dimensions including neck shaft angle, diameter of femoral head, width of the femoral neck, horizontal and vertical offset, acetabular version, acetabular angle of sharp and medullary canal diameter at the level of lesser trochanter in the Indian literature are scarce.

Racial difference

The geometry of the proximal femur is determined by genetic and environmental factors such as age, race, sex and lifestyle. Every patient is unique with individual heredity. Variations in developmental and constitutional factors determine the mechanical integrity, density and shape of bone significantly in proximal femur.

It concluded that the hip joints of the Indian population are evolutionally different on comparing with the Western population. 80% of Indian population is living in villages and their lifestyle is related with agriculture. These persons are apt to ground level activities with increased external rotation and flexion of the hip like kneeling, Asian style squatting and sitting in the floor. Religious and cultural activities requires cross-legged sitting. But fracture implants and prostheses are designed and developed to enable western patients to perform day to day activities like sit at the table to eat, to use western style toilet and climbing stairs. Following a surgical fixation if they do such activities their functional score is termed as excellent. But that may not meet the Indian needs.

Sexual difference

Significance of gender role on osseous anatomy is a blossoming field in orthopedics. Females are constitutionally smaller than males and they tend to have wider pelvis to accommodate birth canal. Hence anthropometric parameters of proximal femur in females do differ from males. Recent researches continue to discover subtle, yet significant anatomical differences between males and females.

Bilateral difference

Loading patterns of right hip joint may not be as similar as the left joint. Hence the probabilities of variations do exist between the sides. This has been already proven by some anthropometric studies.

Indians as a part of the South East Asian population, have a smaller build and stature as compared with the Western counterpart. Commercially smaller and proper sized implants are not available. So there are higher chances of technical errors in total hip replacement.

These anthropometric differences, along with the required range of motion related to the Indian lifestyle (e.g. the squatting position) call for the development of modified hip joint prostheses and implants for the Indian population.

ROLE OF COMPUTED TOMOGRAPHY IN ANTHROPOMETRIC MEASUREMENTS

Computed Tomography (CT) scans are more accurate and easier to obtain measurements than the other methods such as 2D radiographs and direct measurement of cadaveric bones. Neck shaft angle is a peculiar parameter which changes continuously during aging since birth to old age. Hence measurements with cadaveric bones only provide the value in the elder age group which might not represent the entire population. There is also difficulty in measuring intramedullary diameters and identifying the center of femoral head with manual measurements.

Radiographs can only provide approximate value of proximal femur. And acetabular version cannot be measured with 2 dimensional x rays.

The development of 3 dimensional computed tomography has helped in detailed anthropometric study of the hip joint better than the conventional radiography including acetabular anteversion. Magnification has been utilized in improving the accuracy in measurements. PACS (Picture Archiving and Communication System) has been utilized for measuring parameters. Subtle yet significant difference in the parameters can be reliably and reproducibly measured from CT scans.

CT scan is an accurate technique. Most common source of error is patient movement during the examination. Other causes of error are arising from the partial volume effect and beam hardening. And further CT scan equipment, both the source and detector, deteriorate with time. Its higher cost restricts its regular use in clinical studies.

Multislice Toshiba helical CT scanner Alexion TSX-033A in Coimbatore medical college hospital

MATERIALS AND METHODS

MATERIALS AND METHODS

The observational study is conducted in the department of Orthopaedics, Coimbatore medical college and hospital, Coimbatore during the period 2012-2014.

Inclusion criteria:

1. Age 20 - 70 yrs
2. Sex: Both male and females

Exclusion criteria:

1. Persons with pre-existing hip pathologies like osteoarthritis, rheumatoid arthritis, tuberculosis affections of hip.
2. Old fracture or dislocations of hip.
3. Persons with deformities of the lower limb and spine
4. Persons with tumor lesions of hip and proximal femur

Patients attending Coimbatore medical college hospital belongs to south India predominantly from Tamilnadu and also from Kerala and Karnataka states were included in the study. Any patient who is having hip or back pain, old fractures, congenital anomalies like developmental dysplasia of hip etc. are excluded. Total no of 200 patients selected. Patient's height and weight are recorded.

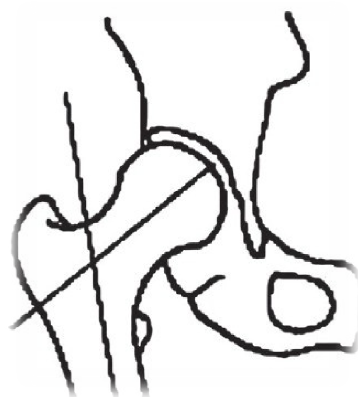
Both right and left sides of proximal femur were analyzed. CT slice thickness is 5 mm. patients were scanned in supine position with both lower limbs in neutral rotation. All the parameters were measured with the PACS (Picture Archiving and Communication System) software. Multislice Toshiba **helical CT scanner** Alexion TSX-033A in the Radiology department of Coimbatore medical college hospital used in our study. The Parameters selected for study were neck shaft angle, head diameter, neck width, acetabular angle of Sharp, horizontal offset, vertical offset, medullary canal diameter at the level of lesser trochanter and Acetabular version. Super-impositions and motion artifacts were avoided. Measuring process is optimized by using the ‘‘full-screen’’ view and the image is magnified to maximize resolution and accuracy.

Patient lying supine with both legs in neutral rotation inside the gantry of CT scanner

MEASUREMENTS

1. ***Neck shaft angle:***

Is measured at the intersection of femoral shaft axis and femoral neck axis. Femoral shaft axis is a line drawn by extending through 2 equidistant points from the medio-lateral surface of femoral shaft in the center of the medullary canal. Neck axis is drawn by joining the two points equidistant from the superior and inferior surface of femoral neck.



Measured neck shaft angle is 133.6 deg

2. ***Head diameter:***

A perfect circle is drawn over the ideally spherical femoral head and circle diameter is measured.

Measured head diameter is 42 mm

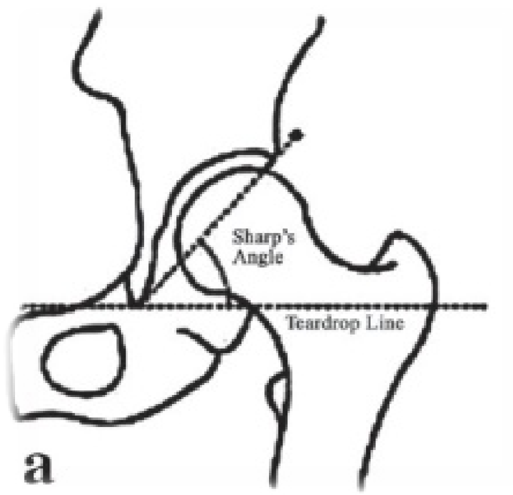
3. Neck width:

A perpendicular line to neck axis is drawn connecting the superior and inferior surface of femoral neck at its narrowest part and the value is measured.

Measured neck width – 23.3 mm

4. Acetabular angle of Sharp:

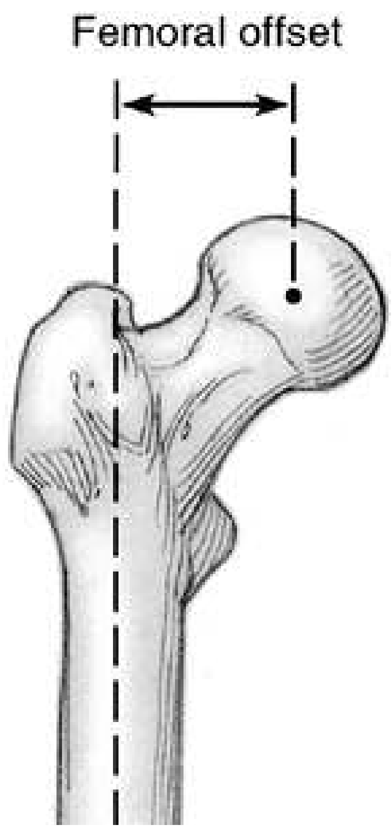
The angle intersected between the horizontal line drawn through the tip of pelvic tear drop and a line drawn from the tip of the tear drop to the anterior edge of the acetabulum.



Measured angle – 37.6 deg

5. *Horizontal offset:*

Or simply femoral offset is the horizontal distance from the center of rotation of femoral head to a line bisecting the long axis of shaft of femur. First femoral head center is identified. And long axis of femoral shaft drawn. The horizontal distance between the two is measured.



Picture showing horizontal offset

6. Vertical offset:

Or femoral head position is the vertical distance from the center of femoral head to the tip of lesser trochanter.

Measured vertical offset – 39 mm

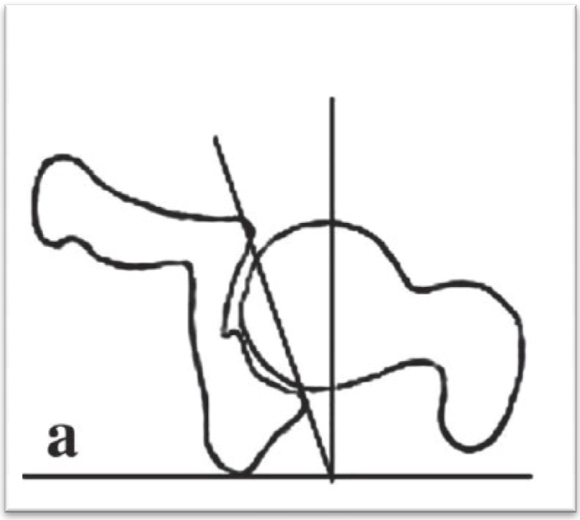
7. Medullary canal diameter at the level of lesser trochanter:

Medio- lateral diameter of medullary canal measured at the level of middle of the lesser trochanter.

Measured medullary canal diameter 21 mm

8. Acetabular version:

It is the angle measured between a perpendicular line drawn to the line connecting both the posterior ischia and a line connecting the anterior and posterior lips of the acetabulum.



Measured acetabular version right – 23.9 & left 21.7 deg

All the values are measured with the ***PACS (Picture Archiving and Communication System) software***. The values are tabulated and the measured parameters are compared with western population. Right and left values and values between male and female are compared and statistically analyzed.

The study was approved by Ethical committee of Coimbatore medical college hospital.

RESULTS

Table showing the obtained parameters in the study

Parameters	Population Mean	Male				female			
		Low value		High value		Low value		High value	
		RT	LT	RT	LT	RT	LT	RT	LT
Femoral head diameter (mm)	42.58	38	40	50	50	36	36	44	46
Neck width (mm)	27.52	19	21	37	35	20	20	31	33
Neck-shaft angle (Deg)	135.43	128	130	147	144	122	124	144	145
Horizontal offset (mm)	37.62	36	35	44	45	33	33	40	39
Vertical offset (mm)	46.89	41	40	65	61	35	41	56	56
Acetabular angle of sharp (Deg)	35.53	24	26	42	42	24	28	42	41
Medullary canal diameter at the lesser trochanter (mm)	20.20	15	13	29	30	13	15	27	24
Acetabular version (Deg)	18.64	11	10	33	29	11	11	33	26

The following values were observed from the data collected during the study of 200 patients in the Department of Orthopaedics, Coimbatore Medical college hospital from July 2012 to august 2014.

In our study, the mean age was 48 years with youngest being 20 years of age and the oldest being 85 years of age.

100 males and 100 females included and both sides of hip joint and proximal femur have been taken into measurements.

Femoral head diameter

Population mean of the above parameter in our study is ***42.58 mm***. In males and females mean femoral head diameter is respectively 44.17 and 40.99 mm and the range is respectively 38 – 50 and 36 – 46 mm. In right and left sides the mean is respectively 42.48 and 42.68 mm and the range is respectively 36 - 50 and 36 – 50 mm.

Neck width

Population mean of the above parameter in our study is ***27.52 mm***. In males and females range of neck width is respectively 19 – 37 & 20 - 33 mm and the mean is respectively 28.90 & 26.14 mm. In right and left sides the range is respectively 19 - 37 & 20 - 35 mm and the mean is respectively 26.94 & 28.11mm.

Neck shaft angle

Population mean of the above parameter in our study is ***135.43 deg***. In males and females range of neck shaft angle is respectively 128 - 147 and 122 - 145 deg and the mean is respectively 136.69 and 134.18 deg. In right and left sides the range is respectively 122 - 147 and 124 – 147 deg and the mean is respectively 134.60 and 136.26 deg.

Horizontal offset

Population mean of the above parameter in our study is ***37.62 mm***. In males and females range of horizontal offset is respectively 35 – 45 and 33 - 40 mm and the mean is respectively 39.84 and 35.40 mm. In right and left sides the range of values are respectively 33 - 44 and 33 – 45 mm and the mean is respectively 37.78 and 37.47 mm.

Vertical offset

Population mean of the above parameter in our study is ***46.89 mm***. In males and females range of vertical offset are respectively 40 - 65 and 35 - 56 mm and the mean is respectively 49.99 and 43.80 mm. In right and left sides the range of values are respectively 35 - 65 and 40 -61 mm and the mean is respectively 47.41 and 46.38 mm.

Acetabular angle of Sharp

Population mean of the above parameter in our study is ***35.53 deg***. In males and females range of acetabular angle of Sharp is respectively 24 -42 and 24 -42 deg and the mean is respectively 35.33 and 35.73 mm. In right and left sides the range is respectively 24 - 42 and 26 -42 deg and the mean is respectively 35 and 36.07 deg.

Medullary canal diameter at Lesser Trochanter

Population mean of the above parameter in our study is ***20.20 mm***. In males and females range of this parameter is respectively 13 -30 and 13 - 27 mm and the mean is respectively 20.65 and 19.75 mm. In right and left sides the range of values are respectively 13 -29 and 13 - 30 mm and the mean is respectively 20.65 and 19.76 mm.

Acetabular version

Population mean of the above parameter in our study is ***18.64 deg***. In males and females range of this parameter is respectively 10 - 33 and 11 - 33 deg and the mean is respectively 17.84 and 19.45 deg. In right and left sides the range of values are respectively 11 - 33 and 10 - 29 deg and the mean is respectively 18.05 and 19.25 deg.

Statistical analysis was done with the various measured parameters with the mean, standard deviation, and range of observations. A p value of less than 0.05 was considered to be significant.

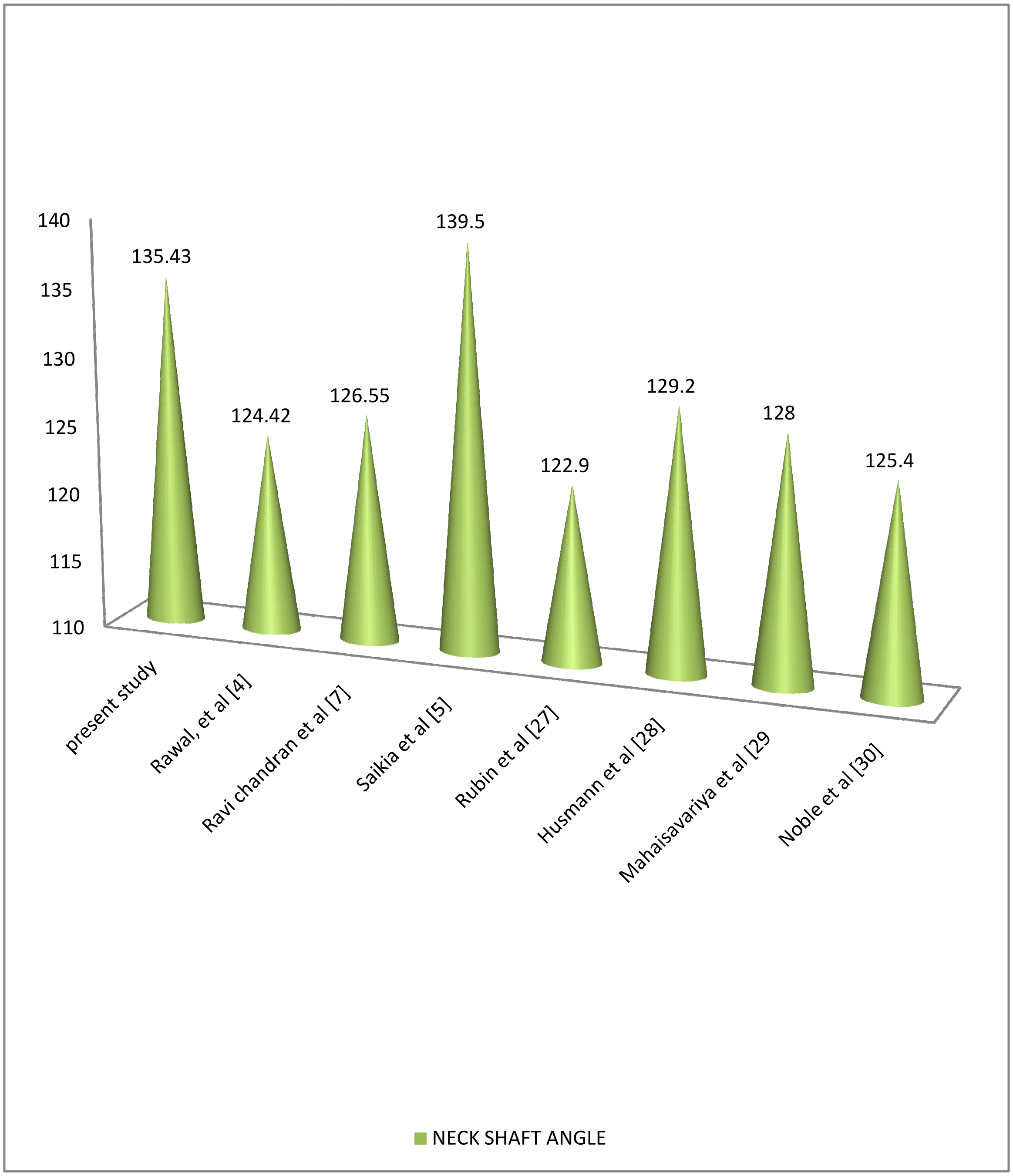
Table 1 analyzes the measurements with the dimensions of the available fracture implants. Table 2 shows comparison of measured parameters with the similar anthropometric studies done in Indian and various regions. Table 3 compares the sexual differences between males and females. Table 4 compares the difference between right and left sides.

TABLE 1

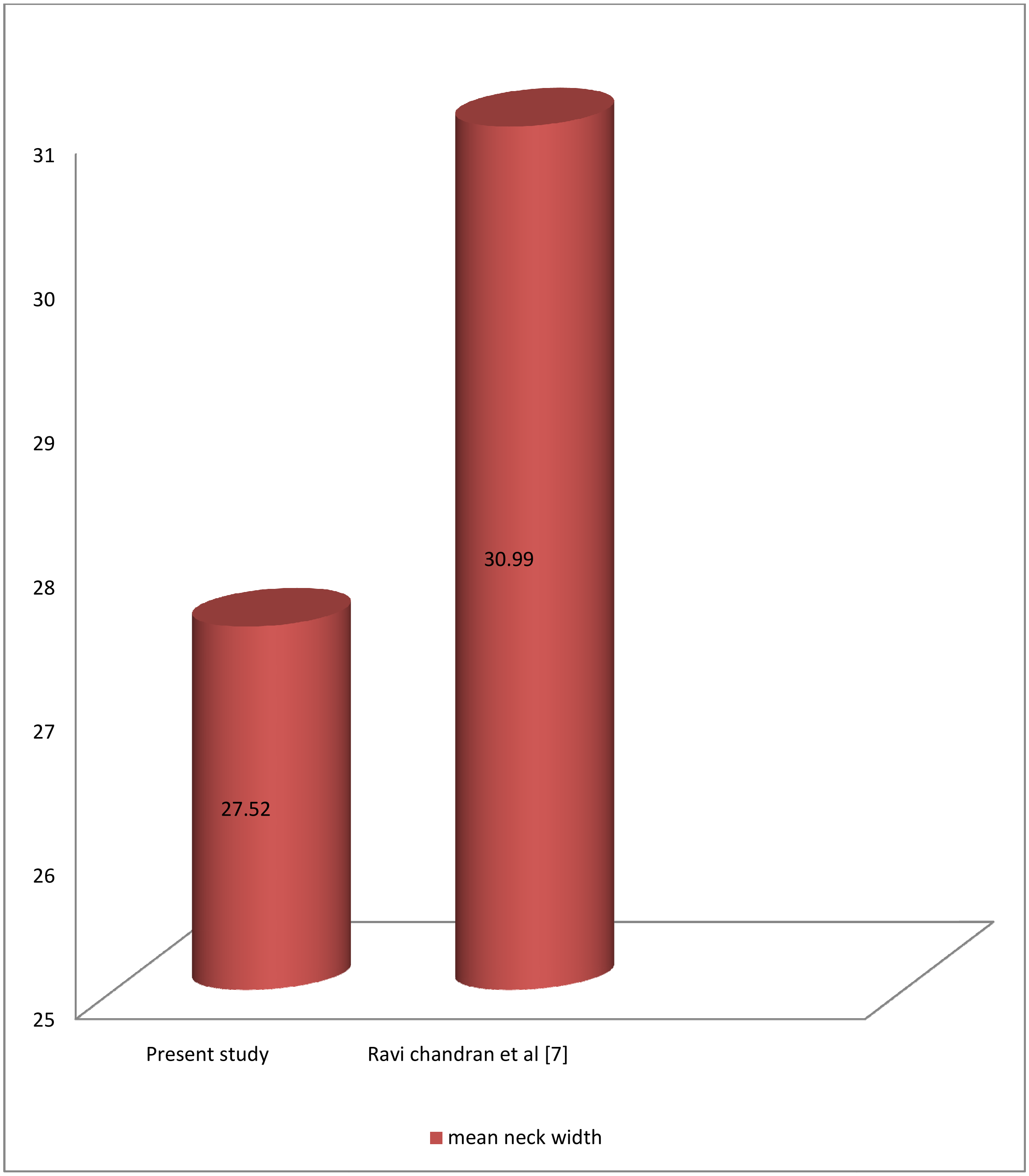
SUMMARY OF THE MORPHOMETRY OF THE PROXIMAL FEMUR REPORTED IN DIFFERENT STUDIES (N = NUMBER OF SPECIMENS)

Parameters	Present study (Indian) (n = 400) Mean	Rawal, et al. [4] (Indian) (n = 98) mean ± SD	Ravi chandran et al [7] (Indian) (n = 578) mean	Saikia et al [5] (Indian) (n = 104) mean ± SD	Rubin *et al* [27] Swiss (n = 32) mean ± SD	Husmann *et al* [28] France (n = 310) mean ± SD	Mahaisavariya *et al* [29] Thai (n = 108) mean ± SD	Noble *et al* [30] Caucasian (n = 80) Mean
Femoral head diameter (mm)	42.58	45.41 ± 3.66	-	-	43.4 ± 2.6	-	43.98 ± 3.47	45.9
Neck width (mm)	27.52	-	30.99	-	-	-	-	-
Neck-shaft angle (Deg)	135.43	124.42 ± 5.49	126.55	139.5 ± 7.5	122.9 ± 7.6	129.2 ± 7.8	128.04 ± 6.14	125.4
horizontal offset (mm)	37.62	40.23 ± 4.85			47 ± 7.2	40.5 ± 7.5	-	-
Vertical offset (mm)	46.89	52.33 ± 7.19			56.1 ± 8.2	57.3 ± 8.1	48.94 ± 4.95	-
Acetabular angle of sharp	35.53	-		39.2 ± 4.9	-	-	-	-
Medullary canal diameter at the lesser trochanter (mm)	20.20	-			27.9 ± 3.6	-	-	-
Acetabular version	18.64	-		18.2 ± 5.6	-	-	-	-

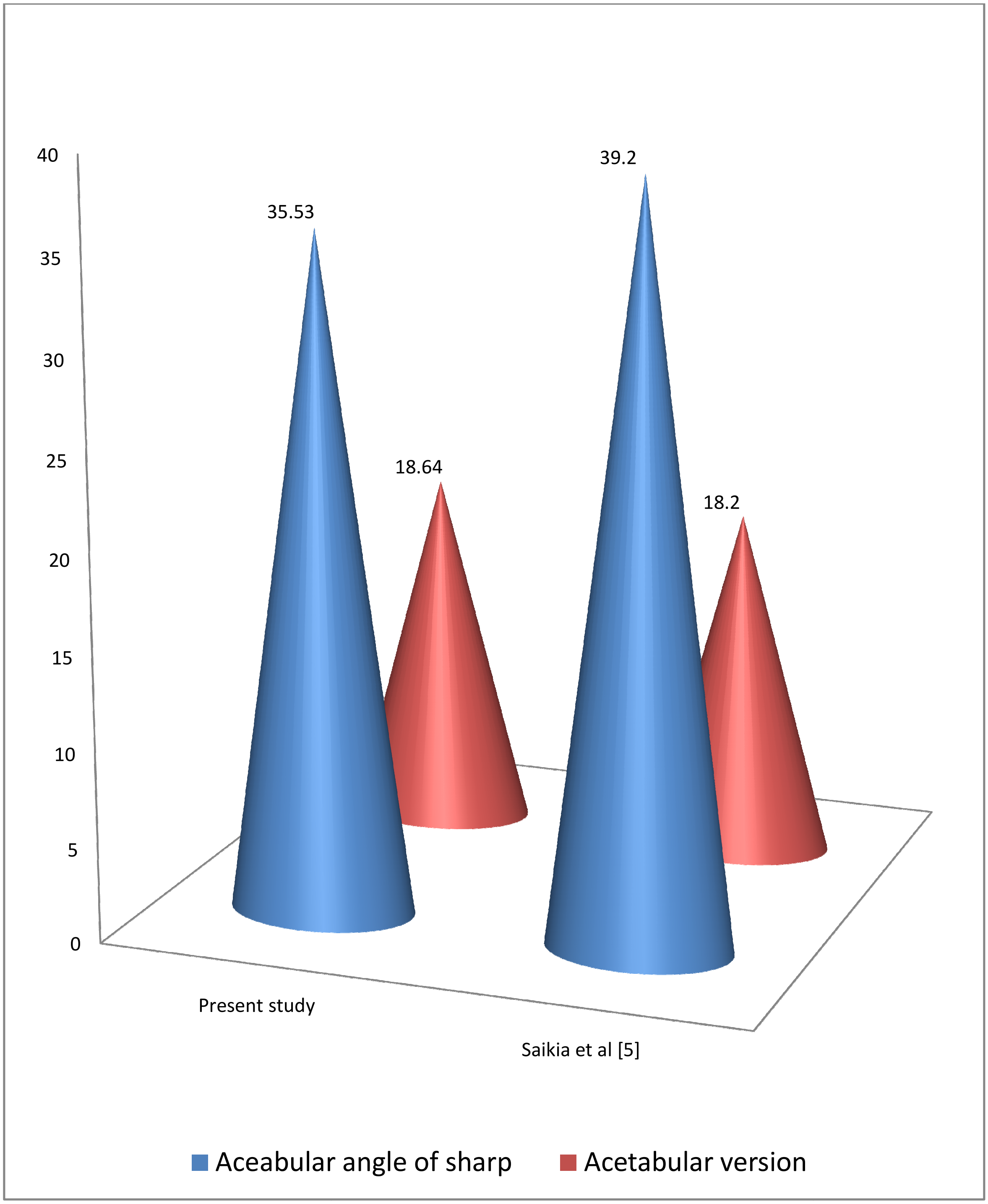
Comparison of neck shaft angle with other studies



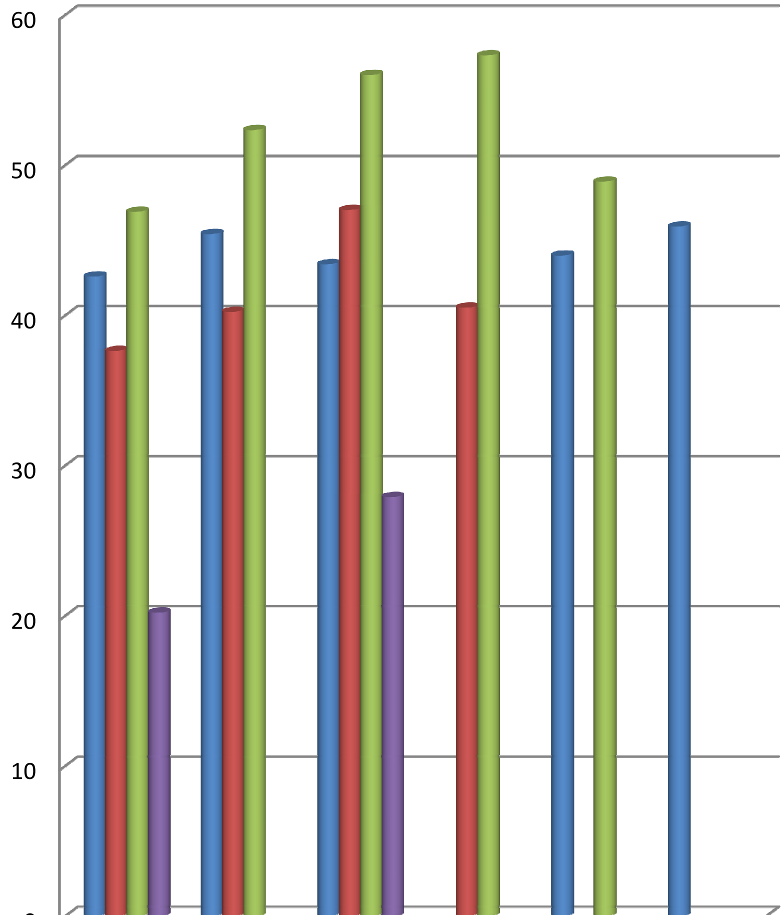
Comparison of mean neck width with other studies



Comparison of Acetabular angle of sharp and Acetabular version with other studies



Comparison of femoral head diameter, horizontal offset, vertical offset and medullary canal diameter at lesser trochanter with other studies



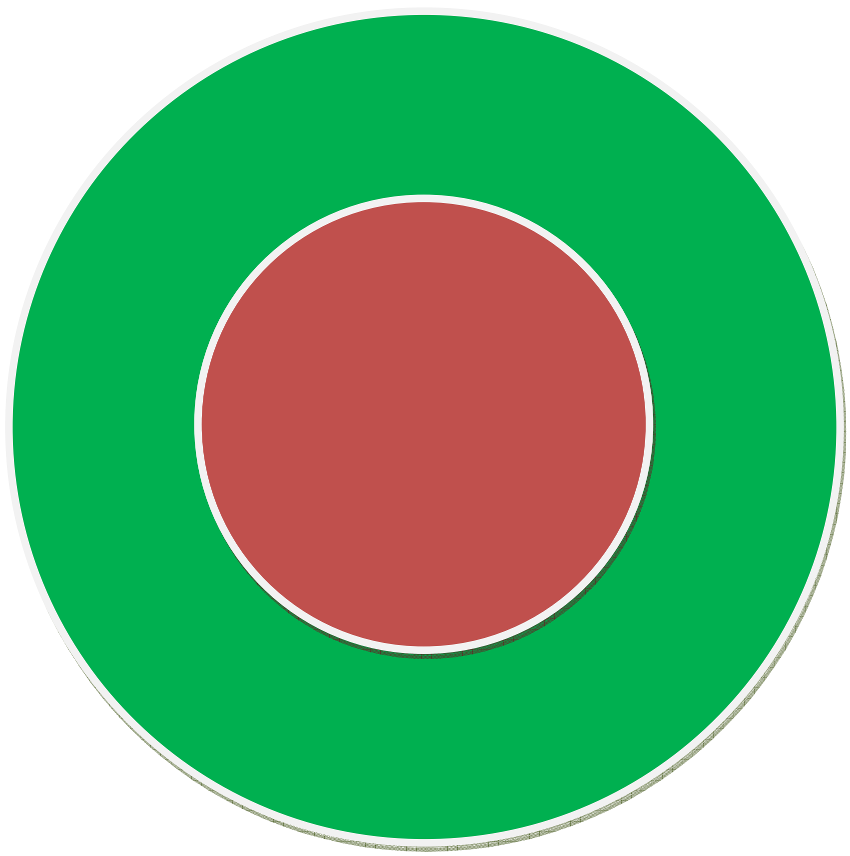
	Present study	Rawal, et al [4]	Rubin et al [27]	Husmann et al [28]	Mahaisavariya et al [29]	Noble et al [30]
femoral head diameter	42.58	45.41	43.4		43.98	45.9
horizontal offset	37.62	40.23	47	40.5		
vertical offset	46.89	52.33	56	57.3	48.9	
medullary canal diameter at LT	20.2		27.9			

TABLE 2

COMPARISON BETWEEN DIMENSIONS OF INDIAN FEMORA AND DIMENSIONS OF FRACTURE IMPLANTS (DHS AND AO SCREWS)

VARIABLE	PRESENT STUDY	DIMENSION OF IMPLANT
Neck shaft angle	135.43	125 -150 deg. (Most commonly used 135 deg)
Head diameter	42.58	1) DHS – 12.5 mm 2)AO screws – 6.5 mm x 3 = 19.5 mm (3 screws most commonly used) 3) PFN – 8 mm (neck screw) + 6.5 mm (anti rotation screw) = 14.5 mm
Neck width	27.527	1) DHS – 12.5 mm 2)AO screws – 6.5 mm x 3 = 19.5 mm (3 screws most commonly used) 3) PFN – 8 mm (neck screw) + 6.5 mm (anti rotation screw) = 14.5 mm

Chart showing percentage of DHS implant occupied in the neck width



Area occupied by the neck width (27.52 mm) 100%

Area occupied by the DHS screw (12.5 mm)45.4%

Chart showing percentage of the femoral neck width occupied by

3 AO screws

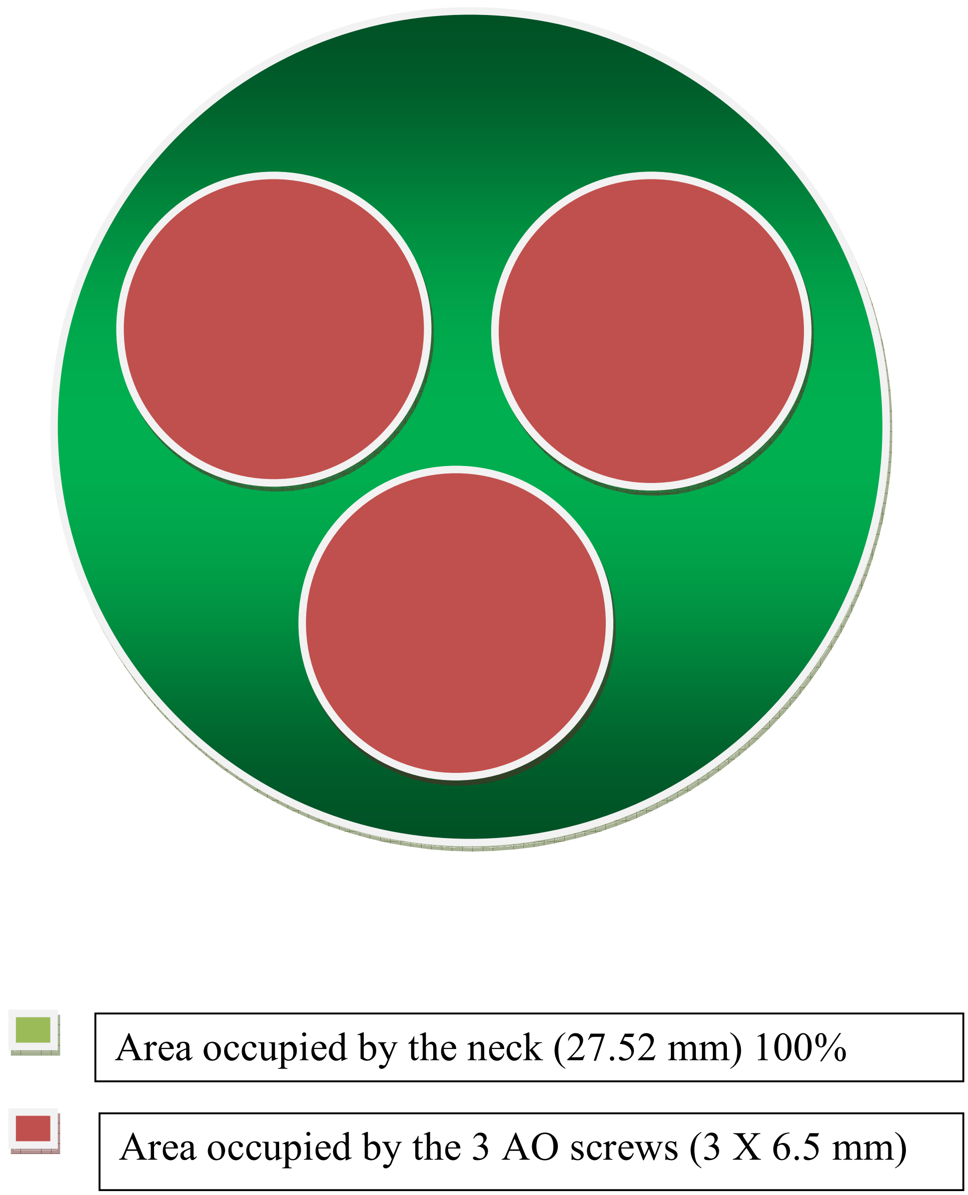


Chart showing percentage of the femoral neck width occupied by 2 screws of PFN

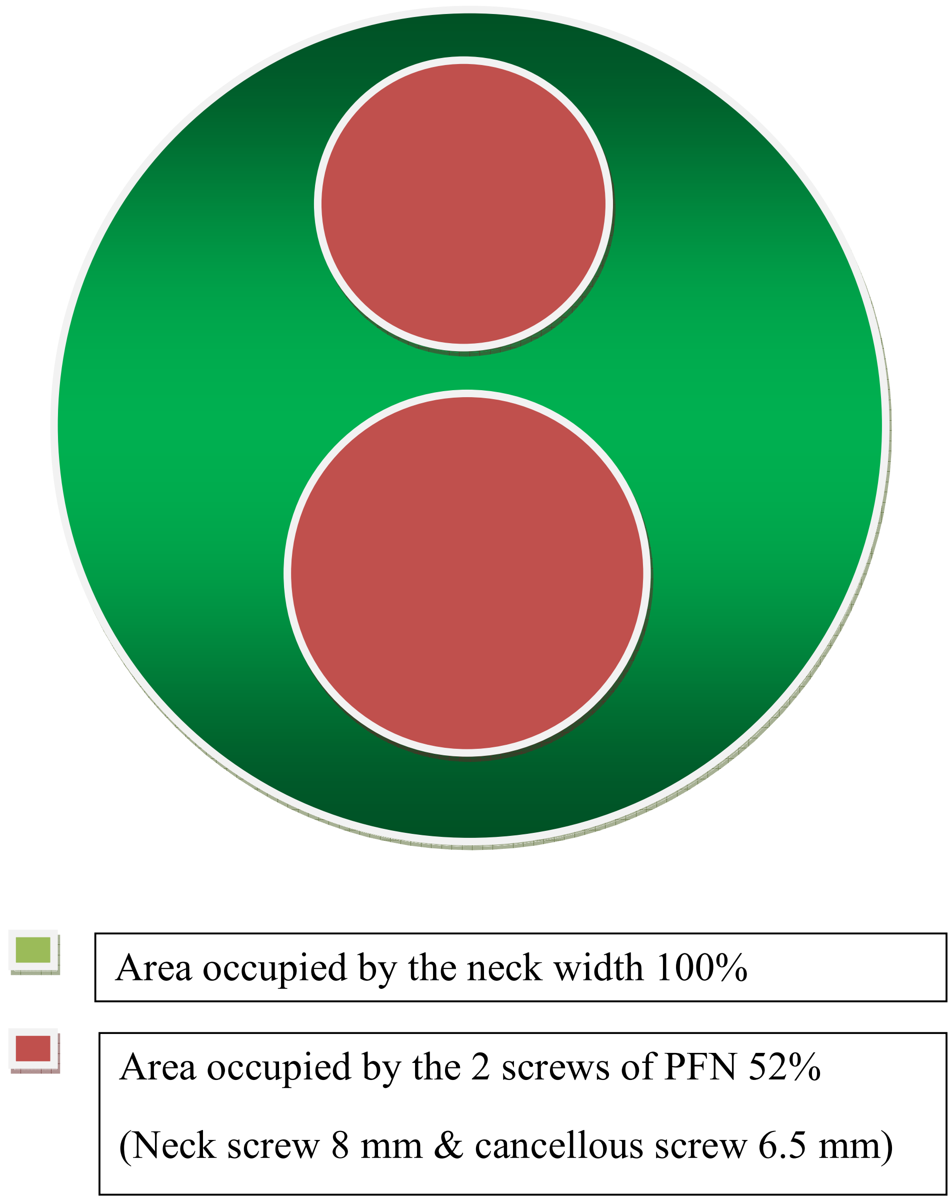
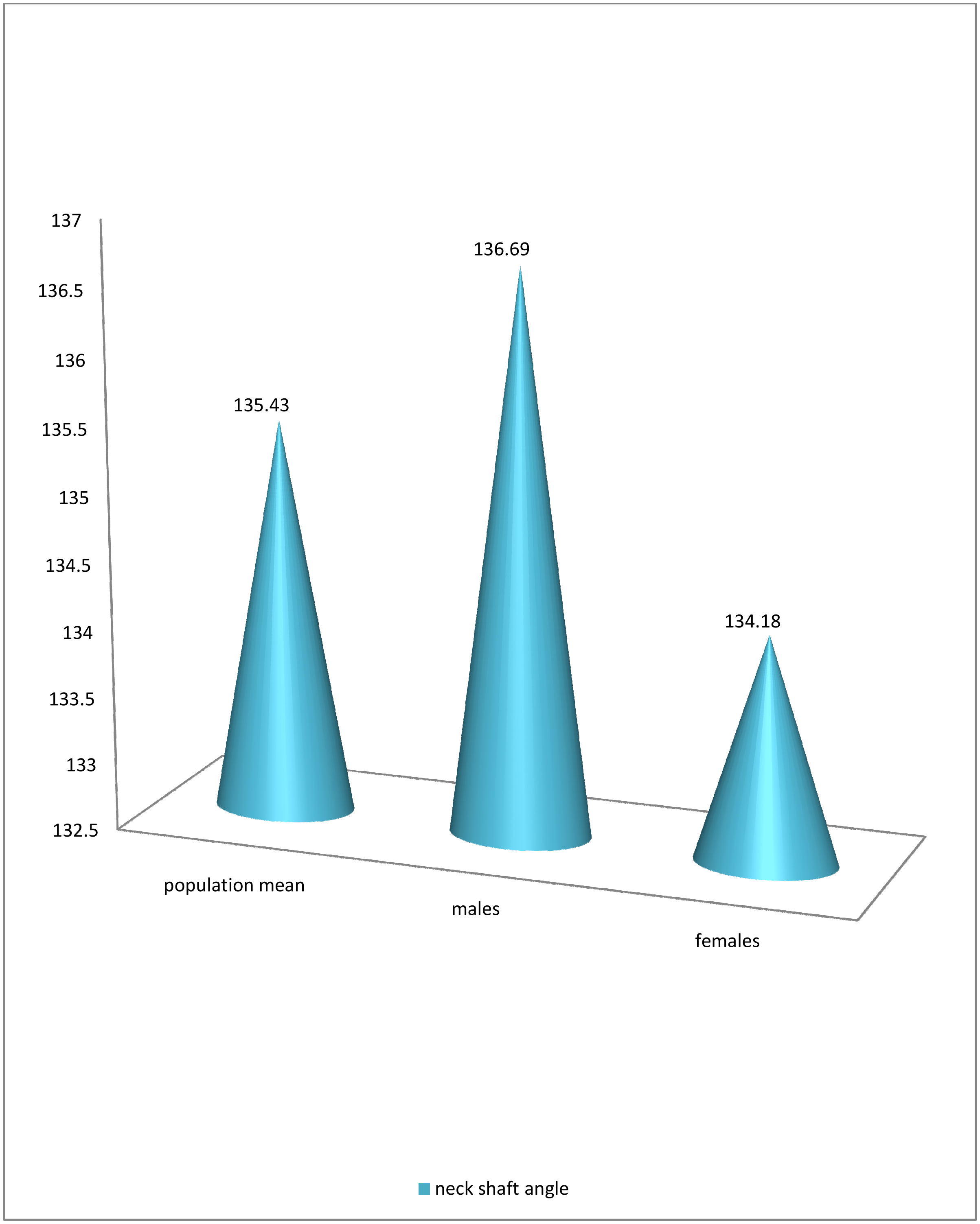


TABLE 3

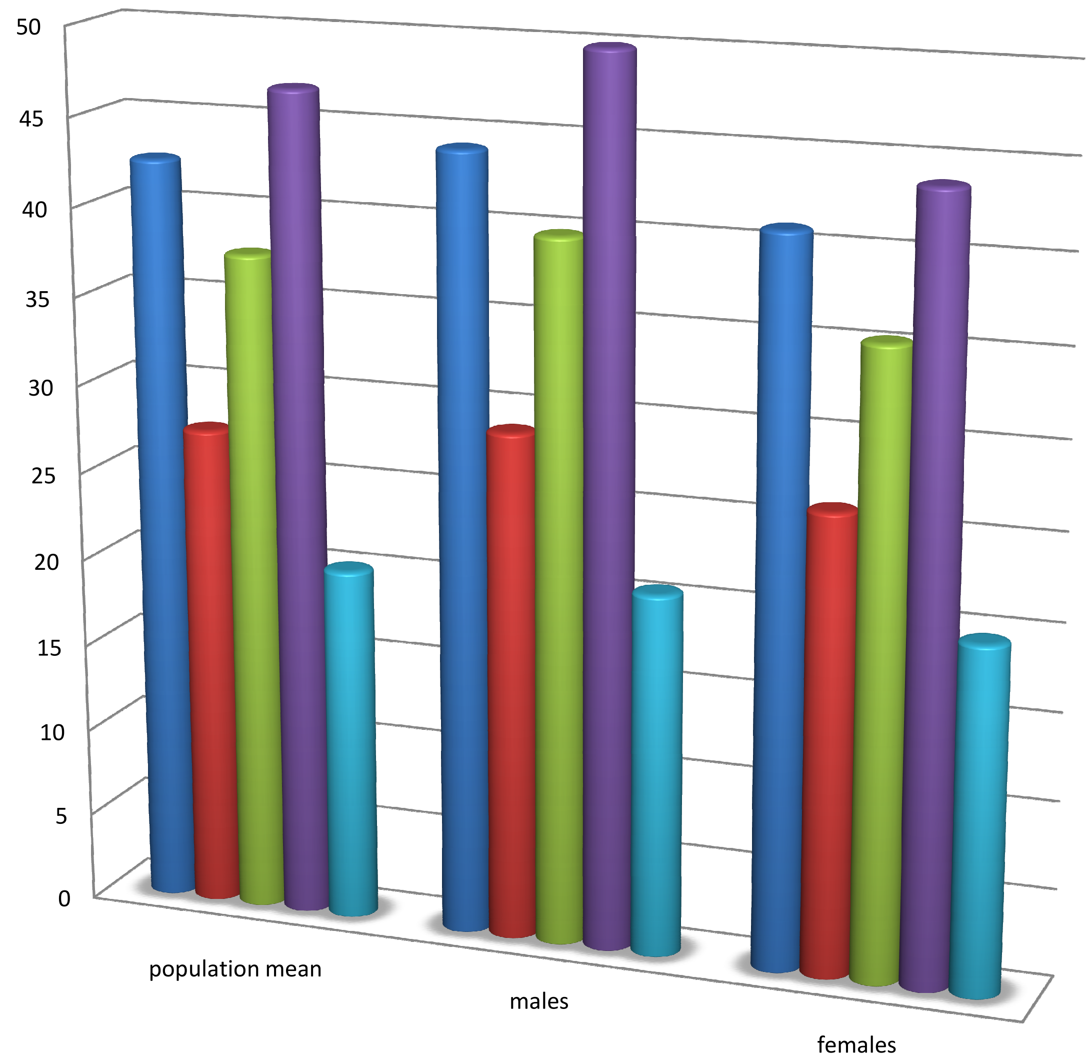
Proximal femoral measurements – mean standard deviation (SD) with p values for Indian female and males

Parameters	Male N= 100			Female N = 100			P – value (significant values underlined)
	Mean	Range	SD	Mean	Range	SD	
Femoral head diameter (mm)	44.17	38 – 50	2.45	40.99	36-46	2.06	<u>≤.0001</u>
Neck width (mm)	28.90	19- 37	2.84	26.14	20-33	2.30	<u>≤.0001</u>
Neck-shaft angle (Deg)	136.69	128 – 147	3.77	134.18	122-145	4.11	<u>≤.0001</u>
Horizontal offset (mm)	39.84	35 – 45	2.04	35.40	33-40	1.47	<u>≤.0001</u>
Vertical offset (mm)	49.99	40-65	4.99	43.80	35-56	4.82	<u>≤.0001</u>
Medullary canal diameter at the lesser trochanter (mm)	20.65	13-30	3.05	19.75	13-27	2.93	<u>.035</u>
Acetabular angle of sharp (deg)	35.33	24 – 42	3.78	35.73	24-42	2.96	.401
Acetabular version (deg)	17.84	10-33	3.76	19.45	11-33	3.88	<u>.003</u>

Comparison of neck shaft angle between males and females



Comparison of femoral head diameter, neck width, horizontal offset, vertical offset and medullary canal diameter at lesser trochanter between males and females



	population mean	males	females
femoral head diameter	42.58	44.17	40.99
neck width	27.52	28.9	26.14
horizontal offset	37.62	39.84	35.4
vertical offset	46.89	49.99	43.8
medullary canal diameter at LT	20.2	20.65	19.75

Comparison of acetabular angle of Sharp and acetabular version between males and females

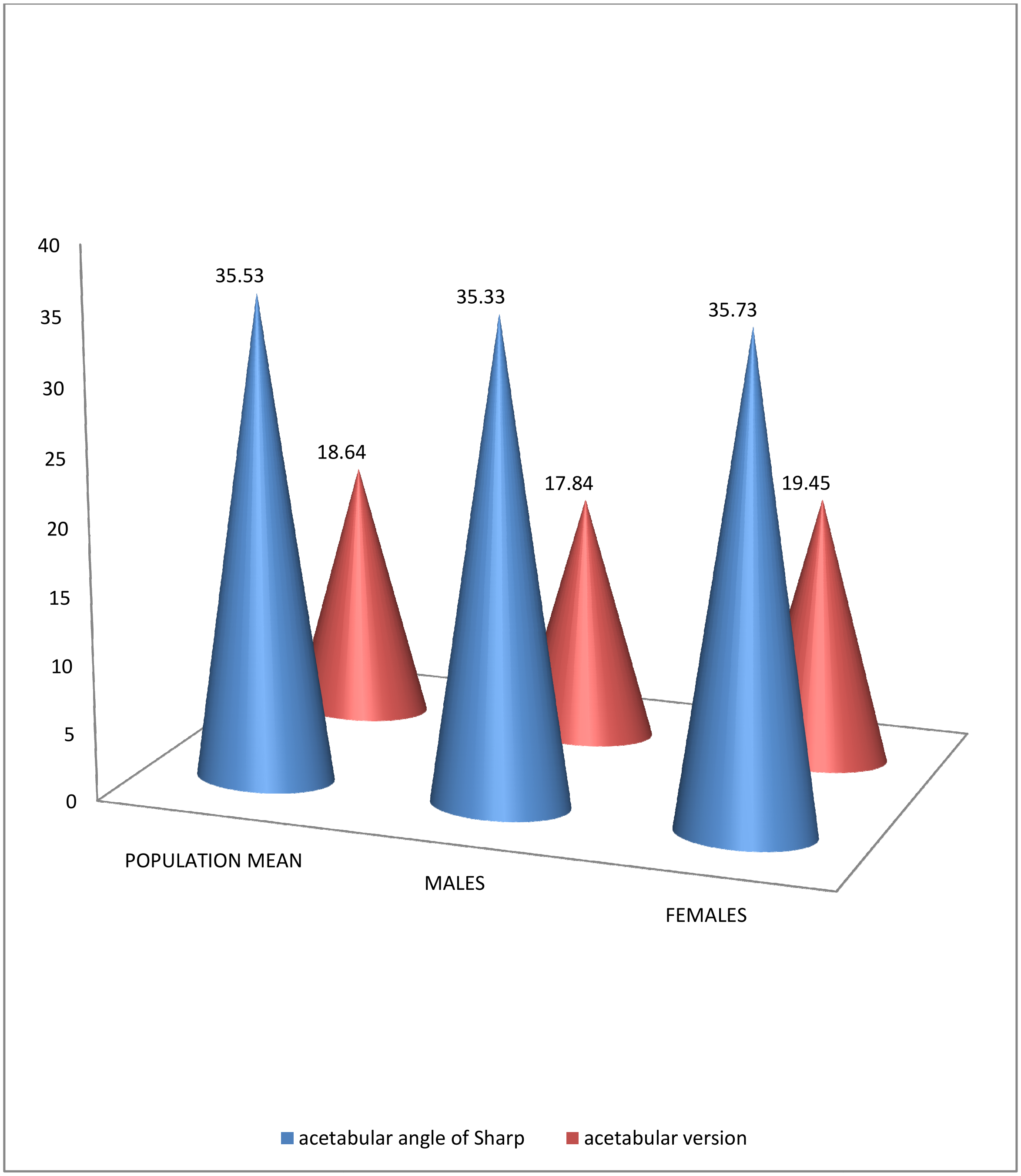
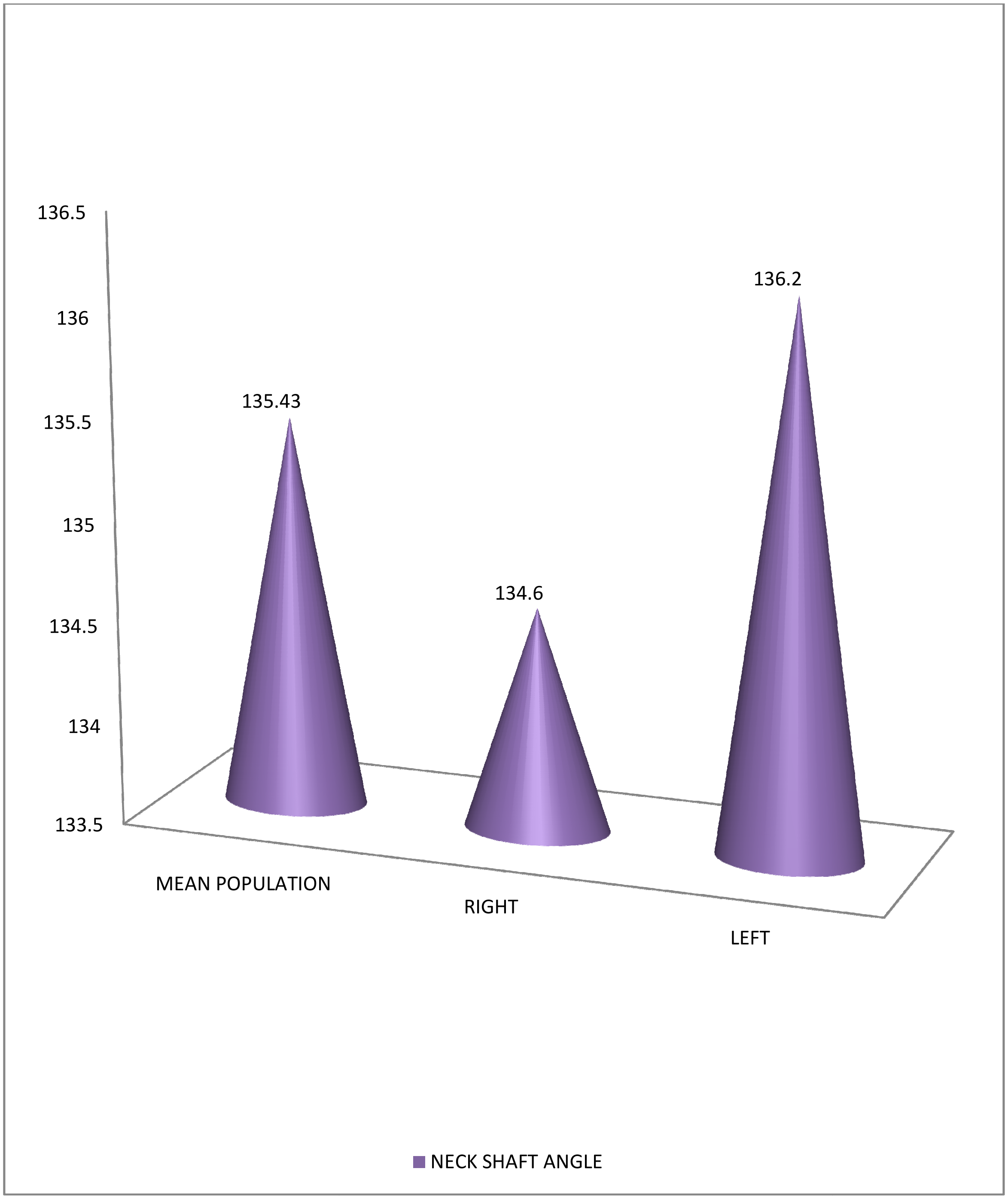


TABLE 4

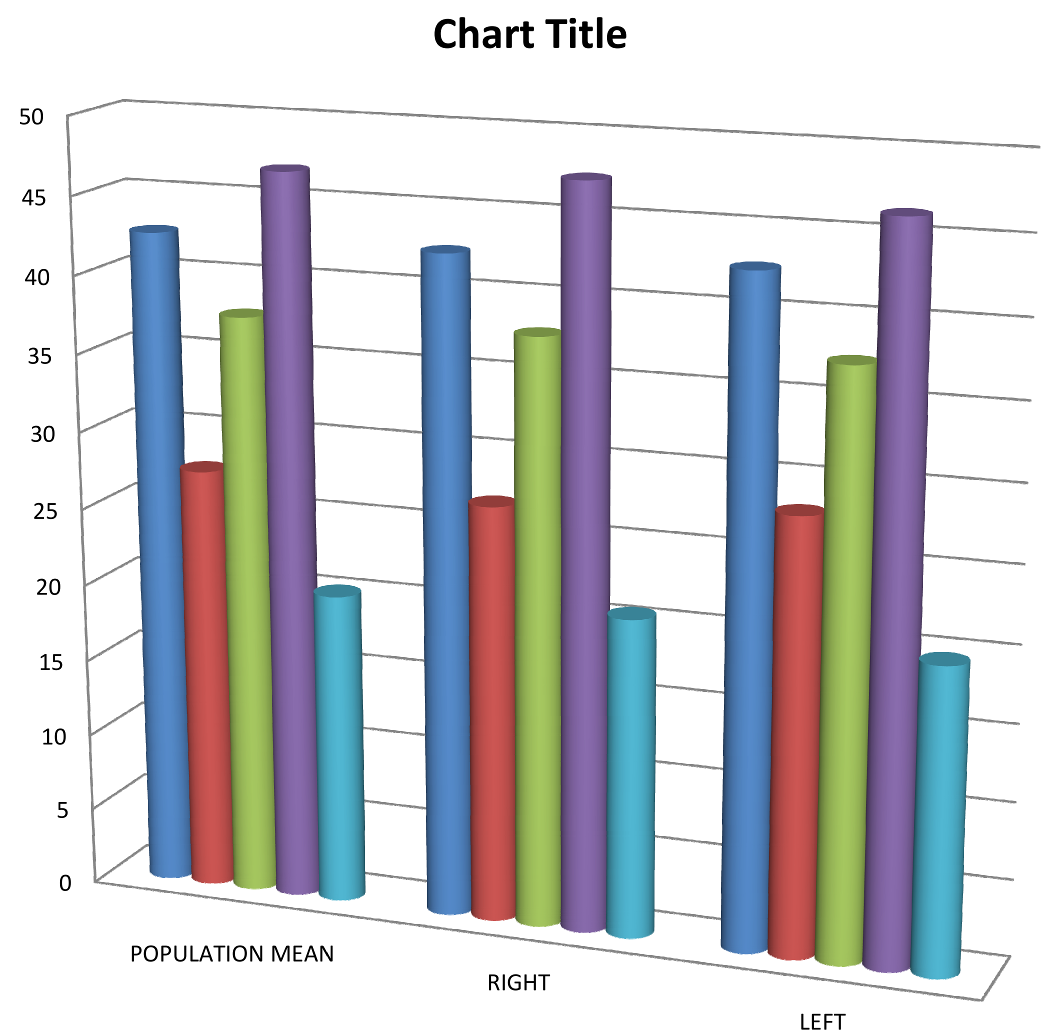
Proximal femoral measurements – mean, standard deviation (SD), standard error with p values for right and left side (N = 200)

variables	Side	Mean	Range	Std. Deviation	Std. Error Mean	P value (significant values underlined)
Femoral head diameter (mm)	Right	42.48	36-50	2.787	.197	**.028**
	Left	42.68	36-50	2.893	.205	
Neck width	Right	26.94	19-37	3.139	.221	**<.0001**
	Left	28.11	20-35	3.171	.224	
Neck-shaft angle (Deg)	Right	134.60	122-147	4.840	.342	**<.0001**
	Left	136.26	124-145	4.136	.292	
Acetabular angle of sharp	Right	35.00	24-42	3.979	.281	**<.0001**
	Left	36.07	26-42	3.656	.259	
Femoral head offset (mm	Right	37.78	33-44	3.393	.240	.154
	Left	37.47	33-45	3.070	.217	
Vertical offset (mm)	Right	47.41	35-65	6.012	.425	**<.0001**
	Left	46.38	40-61	5.964	.422	
Medullary canal diameter at the lesser trochanter	Right	20.65	13-29	3.842	.272	**.001**
	Left	19.76	13-30	3.249	.230	
Acetabular version	Right	18.05	11-33	4.547	.321	**<.0001**
	Left	19.25	10-29	4.011	.284	

Comparison of neck shaft angle between right and left sides

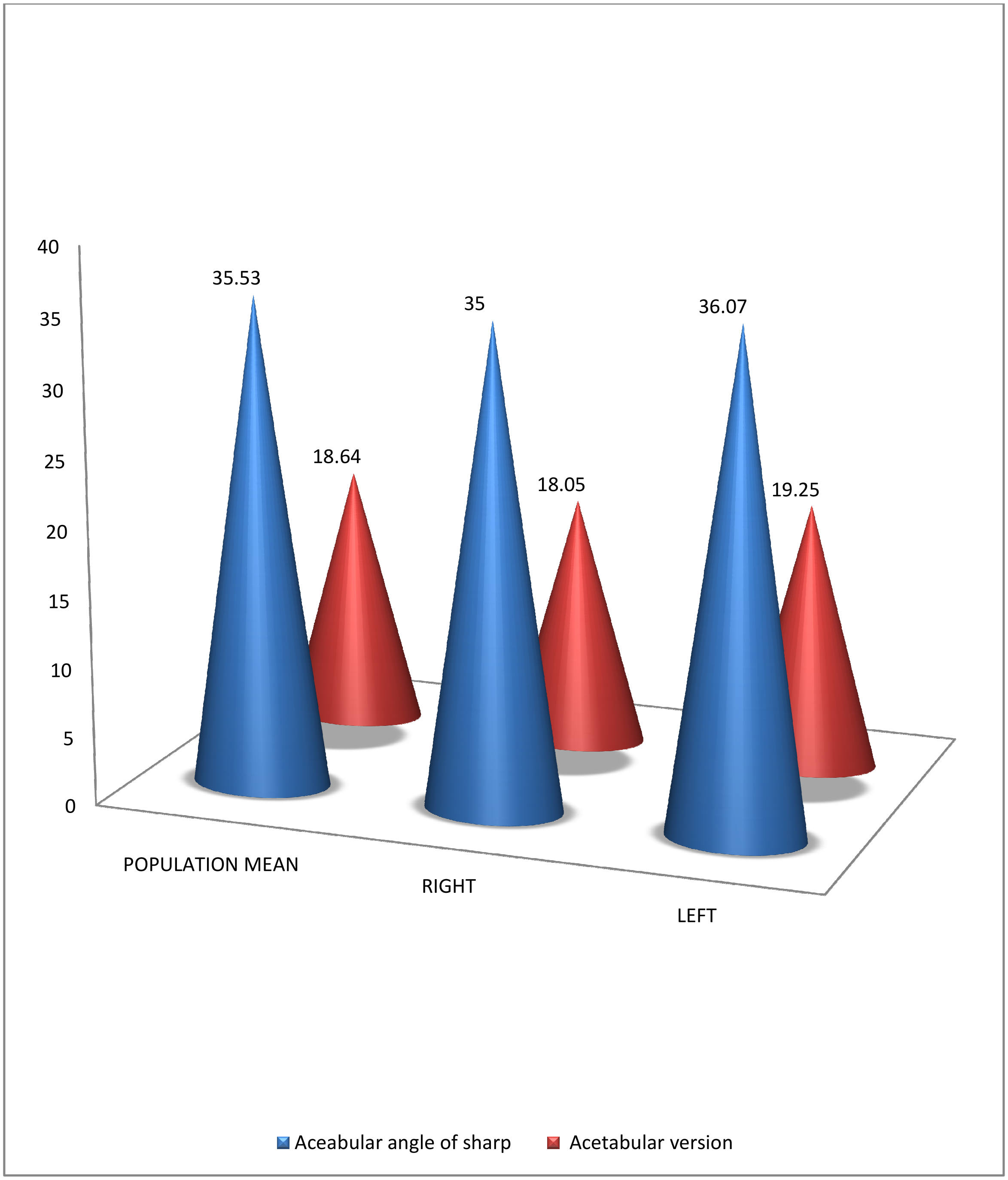


Comparison of femoral head diameter, neck width, horizontal offset, vertical offset and medullary canal diameter at lesser trochanter between right and left sides



	POPULATION MEAN	RIGHT	LEFT
femoral head diameter	42.58	42.48	42.68
neck width	27.52	26.94	28.11
horizontal offset	37.62	37.78	37.47
vertical offset	46.89	47.41	46.38
medullary canal diameter at LT	20.2	20.65	19.76

Comparison Acetabular angle of sharp and of Acetabular version between right and left sides



DISCUSSION

DISCUSSION

Regardless of the volume of research it has generated, the proximal femoral geometry is firmly at grounded status of modern orthopaedics. Critical evaluation of the head-neck relationship is still in relative infancy in India. The literature about the anthropometry of proximal femur in south Indians is scare. Hence analysis of proximal femoral geometry in the south Indian population has been done.

Multiple numbers of factors are identified to influence neck shaft angle in postnatal life. They are femoral epiphyseal perfusion, cartilage activity at the epiphysis, action of muscles, static factors, hormones, body weight and finally, any disease involving the hip joint. Age has the most spectacular influence neck shaft angle.

Evolutionally the hip joints of the Indians would be different from the Western counterparts. Majority of our population are in the agriculture, which requires ground level activities with flexion and increased external rotation of the hip. And cultural activities like performing a Pooja and squatting to use Indian toilets are also considered. In populations with an increasingly sedentary lifestyle and industrialization the mean neck-shaft angles are significantly higher. This reflects the developmental plasticity of the neck shaft angle with respect to changing habitual load levels during development. This infers that neck-shaft angle affected by physical activity and levels of mobility.

We utilized CT for measuring the parameters similar to studies Rawal et al [4] and Saikia et al [5] due to reliability and reproducibility in the living specimens unlike the cadaveric remains which provide the values predominantly in the elder people. Rubin *et al.*[27] also analyzed the parameters using direct methods and radiography and found that using radiography compared to direct measurements the obtained mean difference was 2.4 ± 1.4 mm (mean ± SD), while using CT scans the difference obtained was 0.8 ± 0.7 mm (mean ± SD). In the measured readings the magnitude of errors was very much lower on comparison. Hence he suggested CT scan a better alternative to radiographic and other direct type of measurements. Cadaveric specimens used for measurement in the studies of Ravichandran et al [7] and similar studies [11], [26], [3] & [12]. Mean age of persons in the study is 48 years. In a similar Indian study by Rawal et al [4] the mean age is 61.3 years, who are less active than our study.

Table 1 compares the extracted anthropometric measurements of south Indian population with the published parameters of other regions of the world. The methods used in such studies were radiographic for Husmann et al [28] and Noble et al [30]. Rubin *et al* [27] and Mahaisavariya *et al* [29] used CT scans. Hence, the measured parameters from this study and other previous studies (involving radiographic and CT scan measurements) can still convey an accurate idea regarding the differences in anthropometric measurements.

In the study the femoral head diameter was 42.58 mm (Range 38 – 50 mm). In a similar Indian study of Rawal et al [4] the value is 45.41 mm, and in Rubin et al [12] and similar western studies [29], [30] the mean values are respectively 43.4, 43.98 and 45.9 mm. In the study the mean neck width was 27.52 mm (range 19-37 mm) which is smaller than 30.99 mm observed from the Ravichandran et al [7].

Neck Shaft Angle (cervico diaphyseal angle, collo diaphyseal, or angle of inclination):

Femoral neck forms an angle with the shaft which is usually 135±7° in the normal adult. Functional significance of this angle is that the displacement of femoral shaft away from the pelvis facilitates freedom of hip joint motion. When there is a significant deviation of this angle outside the normal range, the lever arms of the abductor muscles will either be too large or too small, affecting the freedom of hip movements.

In the study mean neck shaft angle is 135 deg (range 128-147 deg). The parameters obtained from Rawal et al and other studies [26], [7], [27], [28], [29] & [30] are respectively 124, 126, 122, 129, 128 and 125 deg and they are lower than our value. Another Indian study using CT scan was done by Saikia et al [5] found the angle to be 139 deg. The angle showed a difference of 12 deg on comparing with the Swiss population done by Rubin *et al* [27].

Humphry (1889) noted [36] that there is an inverse relationship exists between the neck-shaft angle and biomechanical loading levels of hip joint. Femoral neck-shaft angles are particularly very high (around 150°) in intrauterine and in neonatal period and then gradually the angle decreases during development. It reaches adult values during the adolescent period then there is a minimal decrease in the angle. This is due to changes in proportions of the body followed by more vertical adaptation of the hip joint and change occurs in gait pattern from crawling to running. Anderson et al in his study noted an association of lower neck shaft angles with higher levels of weight bearing [36].

Significance of neck-shaft angle in designing femoral stem is that, greater horizontal offset is seen with low neck-shaft angle, and less horizontal offset is seen with high neck-shaft angle like in the study. ***Neck stem angle of the femoral stem is 131 deg***. The ***mean neck shaft angle in our study is 135 deg***. When these differences are not considered while performing THR, this may not restore the normal hip biomechanics. Available cephalo cervical diaphyseal angles in PFN are 130 and 135 deg. In our study variations noted in neck shaft angle is from 122 – 147 deg. Hence a **routine PFN might not reproduce the normal neck shaft angle following surgical fixation in a patient with the angle of 122 deg**.

Acetabular angle of Sharp is a determinant of acetabular dysplasia. Acetabulum is considered dysplastic when the value is more than 43 deg. In the present study mean angle is 35.5 deg compared to value of 39.2 deg by Saikia et al [5]. Stuberg and Harris [42] found mean acetabular angle of 32.2 and 32.1 deg in white males and white females respectively. Nakamura et al [43] observed mean of 38 deg in the Japanese population. CT is a precise technique in detecting acetabular dysplasia which can be utilized before performing THR.

In the study femoral horizontal and vertical offsets are respectively 37.62 (range 35-45 mm) and 46. 89 mm (40 - 65) in our study, which is much lower than the values observed by previous studies of Rawal et al [26], Rubin et al[27], Husmann et al[28] and Mahaisavariya et al[29]. But vertical offset is in close comparison with the study of Thai population by Mahaisavariya et al [29], with the mean value of 48.94 mm whose constitution and body height is much lower than rest of the world. The difference in femoral head offset difference found to be 10 mm between our study and Swiss populations done by Rubin *et al* [27]. In vertical offset the maximum difference of 11 mm found between our study and in French population done by Husmann *et al* [28]. This indicates that when using the same implant designed for Swiss population in Indians can cause significant soft tissue tension in and around the joint. This can also increases the chances of post operative dislocation.

Medullary canal diameter measured at the level of lesser trochanter in our study is 20.20 mm (range 13-30 mm). Saikia et al [5] found the value to be 27.9 mm with the standard deviation of 3.6. Hence implanting a standard femoral stem designed for western population inside the proximal femoral medullary cavity of south Indians can cause splinters and fractures. Therefore designing a femoral stem specific to Indians with these observed values can augment the essence of surgical fixation.

Acetabular version measured in our study is 18.64 (range 10 - 33) deg. Mean acetabular version observed by Reikeras et al [44] was 17 deg and standard deviation was 6. Saikia et al [5] observed the acetabular version as 18.2 deg similar to our study. Recommended acetabular version while placing the interfit acetabular cup in THR is 20 deg but variations from 11 – 33 deg were noted in our study. When these differences are not considered while performing THR, this may not restore the normal hip biomechanics. Hence performing a CT scan before an arthroplasty can assist in restoring the acetabular version while performing THR.

Table 2 compares the parameters found in the study with the dimensions of the available fracture implants. While functioning alone, neither implant nor bone cannot provide adequate stabilization at the fracture site. Motion at the fracture site hinders bone healing. When the fracture is stabilized by the implant, the bone will regrow over a sufficient period of time across the fracture site. Later bone will protect the implant. When a larger implant in question is used for fracture fixation, it requires drilling which removes the bone. When sufficient bone stock is not available for an effective fixation, implant will fail as the regrowing bone cannot take over the function of implant. This is called implant fatigability. Hence use of these implants negates the purpose of surgical fixation on long term, and affects the functional end result of surgery.

Insertion of any screw requires drilling. This removes the available cancellous bone in the neck and head of femur. And screws with large thread diameter occupy greater area in the neck and head of femur after reaming. Such a large drilled hole in the neck of Indian femora takes away excess amount of viable cancellous bone.

The thread diameter of the DHS is 12.5 mm. ***Average neck width in the study is 27.52 mm***. Hence ***DHS screw occupies 45.42 % of the neck width***. Insertion of this screw requires reaming with DHS triple reamer and tapping. This removes large cancellous bony stock cylinder from the head and neck of femur. And these implants would occupy a larger area in the neck and they can jeopardize the blood supply to the head leading to avascular necrosis and non union.

AO recommends 3 AO screw fixation in fracture neck of femurs**.** ***3 AO screws occupy 70.8 % of the mean neck width in our study.*** It is increasingly difficult as the available area is small, especially in an Indian female, orthopedic surgeons end up in fixing with 2 screws. As per our study ***the lowest value of neck width is 19 mm***. in that case scenario***, inserting 3 AO 6.5 mm cancellous screws as per the AO guidelines of fracture fixation may not possible.***

In ***Proximal femoral nailing 2 screws*** are used for fixation of proximal femur. One is neck screw with the thread diameter of 8 mm and another one is anti rotation screw with the diameter of 6.5 mm. These ***two together occupy 14.5 mm which is 52 % of our average neck width.***

These differences can therefore, significantly affect the performance of fracture implants and standard size femoral stem for cementless fixation, as mentioned by Hua and Walker [31]. When there is no optimal contact between bone and femoral stem presence of micro motion hinders bony in growth, thereby causing secondary instability over a period of time. Also, when the subtle yet significant differences are not considered in bioengineering of implant designs, distribution of load will be affected, leading to fatigue failure and high likelihood of breakage of the stem which has been mentioned by Ducheyne *et al* [32].

Table 3 shows the mean values of femoral dimensions for the male and female subjects separately. Mean values for male subjects were found to be higher for Femoral head diameter, Neck width, Neck-shaft angle, Horizontal offset, Vertical offset and Medullary canal diameter at the level of lesser trochanter. Above mentioned parameters are statistically significant. Remaining values the ***acetabular version and acetabular angle of Sharp higher in females***. Among it acetabular version found to be statistically significant. This could be due to the existing differences in size, shape and load distribution changes at the hip joint between the males and females.

Differences in the measurements of width and length of proximal femur between the sexes had been already discovered and application of this knowledge has been utilized in identification of sex in dismembered murder victims by forensic anthropologists [33].

Difference in horizontal offset between the male and female is approximately 4 mm. Comparing males***; in females the neck of femur forms a shallower angle*** with the shaft. The above data reveals that there might be relative amount of difficulty in implanting standard femoral stem to a female patient during total hip replacement.

Hence matching an implant might be done separately for males and females especially for cementless femoral stems for a better operative outcome. This can be done with 2 key extramedullary dimensions; leg length (or vertical offset) and horizontal offset. Both helps in preserving proper hip biomechanics and improves overall post surgical patient satisfaction in Total Hip Replacement[34][35]. Before implantation, optimizing the above mentioned parameters can restore the leg length, joint stability and range of motion.

Table 4 shows the mean, range and standard deviation values of proximal femoral dimensions for the right and left sides. ***Mean values for left side were found to be higher*** and statistically significant for Femoral head diameter, Neck width, Neck-shaft angle, Acetabular angle of Sharp and Acetabular version. For the horizontal offset, vertical offset and medullary canal diameter at the level of lesser trochanter right side values found to be higher. Among that all are statistically significant except horizontal offset. Various authors noted left side values were higher [45] & [46]. Saikia et al [5] found most of the values are higher on the left side but only the neck shaft angle was statistically significant in his study.

CONCLUSION

CONCLUSION

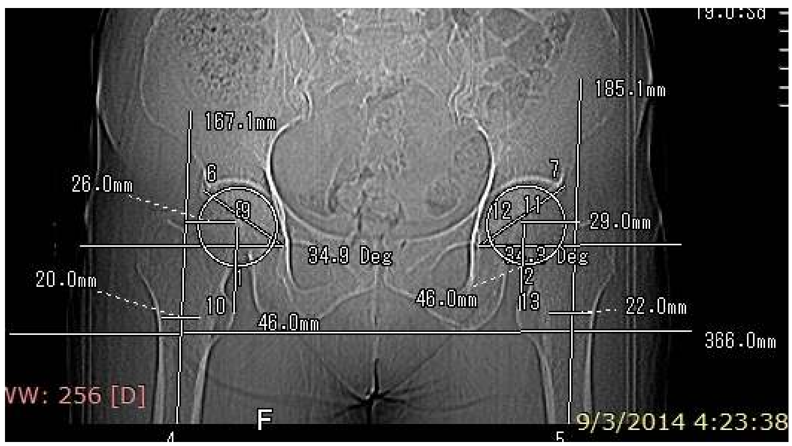
In this study analysis of proximal femoral geometry was done in 200 south Indian people by CT scan in our Coimbatore medical college hospital. There are significant differences in anthropometric parameters of proximal femora found in the south Indian population on comparing with western population. Even within the Indian population between males and females, and between right and left differences were identified. Improving the knowledge about the proximal femoral morphology will help the surgeon to restore the geometry to restore the hip offset and hip biomechanics.

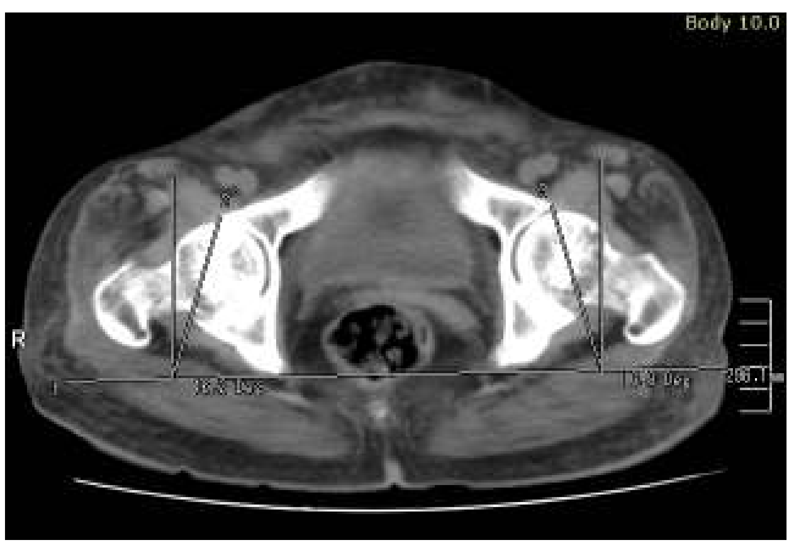
Our study indicates that specific fracture implants and replacement prosthetic designs are needed to reduce the post operative complications on long term. Considering these geometries would eventually improve the postoperative outcome, and eliminate the possibility of a revision surgery. Increased awareness in the average dimensions of the femoral head and acetabulum will assist biomedical engineer in designing a better implant pertaining to the patient’s need.

Our study was done with only 200 candidates. A large multicentric study is necessary to confirm our results. In the era of customized implants, when every human is considered unique, it is mandatory to design prosthesis which is specific for Indian population. Due to the lesser amount of anthropometric studies, specific hip implants and prosthesis are not yet been developed for the Indian population. This study will enlighten the prosthetic designers to design a specific implant for Indian needs.

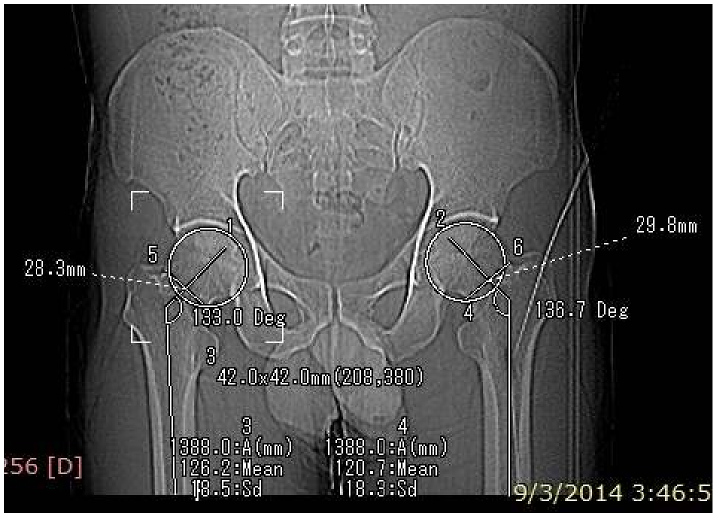
CASE ILLUSTATIONS

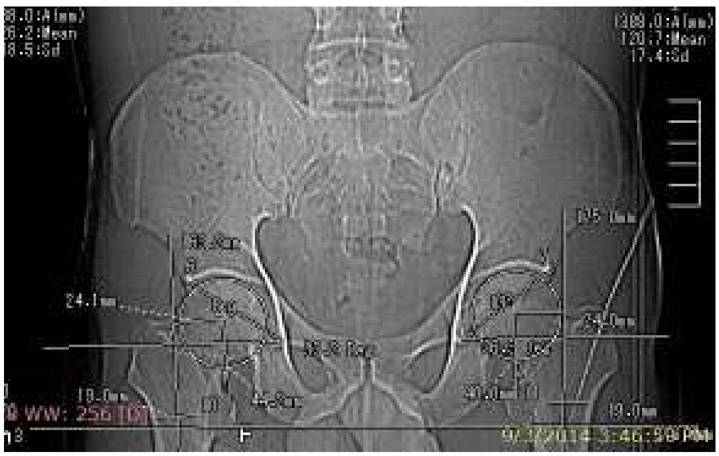
Parameters of 54 years old female

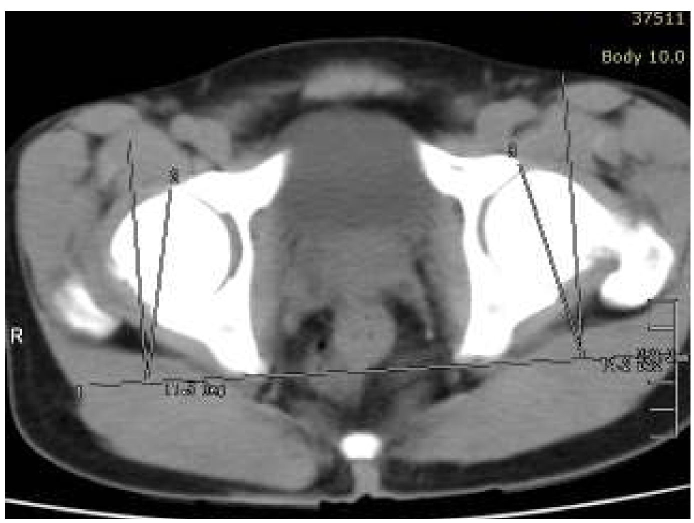




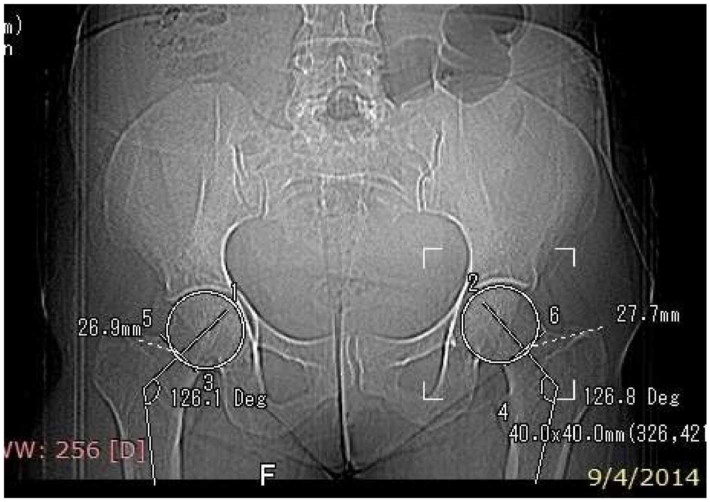
Parameters of 36 years old male

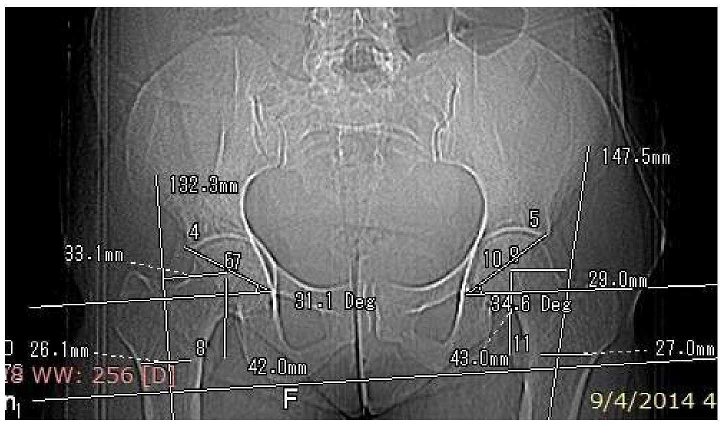




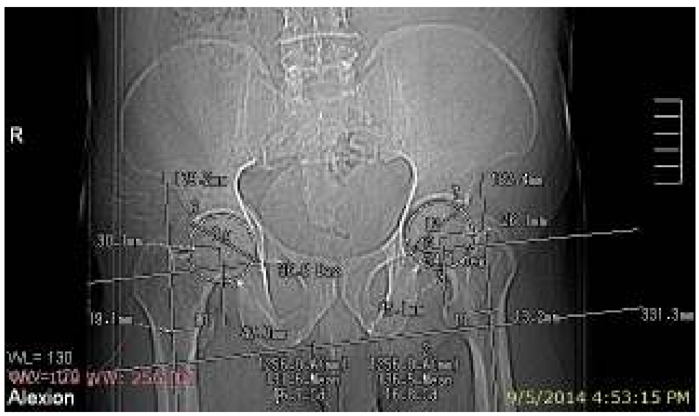


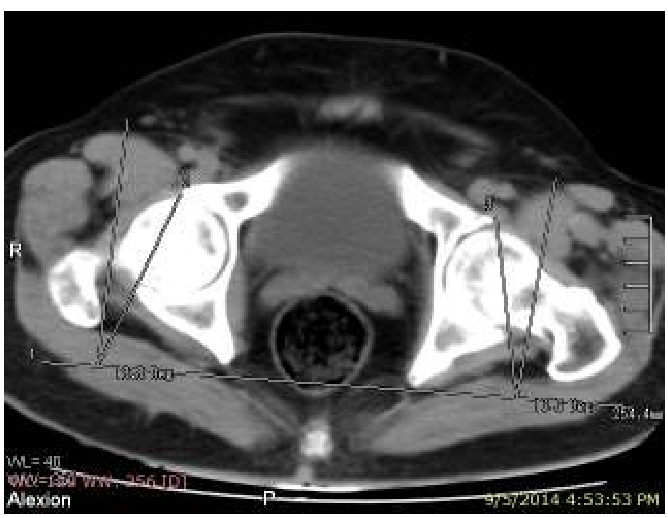
Parameters of 55 years old female



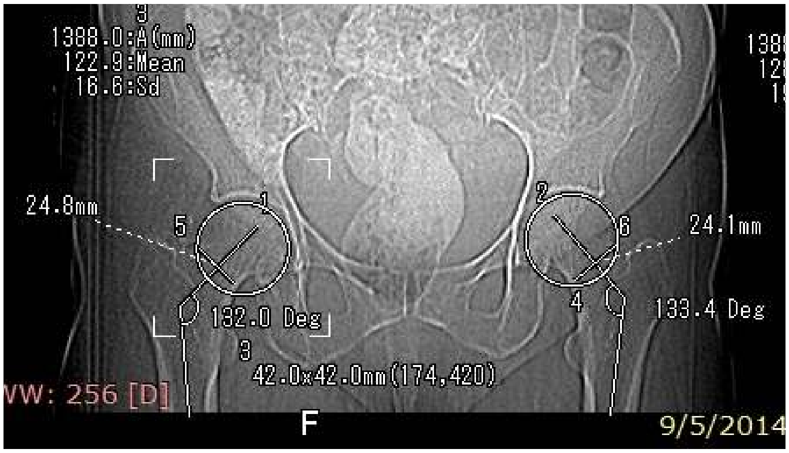


Parameters of 65 years old male





Parameters of 75 years old female



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ANNEXURES

PROFORMA

Patient Name: **Age:** **Sex: M / F** **OP/IP No :**

Occupation:

Address:

Presenting complaints:

Clinical Evaluation

Ambulation : **Any Spine pathologies;**

Any Congenital anomalies: **Previous hip or spine surgery:**

Local examination of Hip region

Skin condition

Deformity

CT scan findings:

Spine:

Acetabulum:

OA changes: **Dysplasia:**

Para meter	Femoral head diameter	Neck width	Neck shaft angle	Acetabular angle of Sharp	Horizontal offset	Vertical offset	Medullary canal diameter at LT	Acetabular version
Value								

MASTER CHART

MASTER CHART

S.NO	NAME	AGE/ SEX	FEMORAL HEAD SIZE		NECK DIAMETER		NECK SHAFT ANGLE		SHARP ANGLE		HORIZONTAL OFFSET		VERTICAL OFFSET		MEDULLARY CANAL DIAMETER AT LT		ACETABULAR VERSION	
			RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT
1	SRIRANGAMMAL	70/F	44	42	27.7	29.8	127.7	138.6	29	36	34	36	43	45	17	19	24	20
2	RAJESHWARI	45/F	36	38	31.1	31.9	140.9	140.5	34	38	36	36	47	48	19	19	18	20
3	RENUGA	42/F	38	42	26.4	28.2	133.5	141.3	37	40	37	33	46	42	17	18	19	21
4	JOTHIMANI	26/F	40	38	24.8	23.4	138.7	135.9	40	43	33	34	43	43	17	20	22	24
5	BHUVANA	40/F	40	42	24.8	26.1	143.4	145.2	30	32	35	34	46	46	16	18	18	19
6	NILFARNISHA	30/F	38	34	22	25	133.1	141.1	37	38	36	37	47	44	17	16	14	14
7	RAJI	61/F	40	44	26.2	27.2	144.7	142.2	34	38	36	33	47	48	19	19	18	20
8	SUBHADRA	53/F	38	36	21.9	19.8	136.4	138.9	40	38	33	36	43	45	22	17	26	24
9	RUCKMANI	60/F	44	46	31.1	31.9	132	135	38	38	34	34	50	50	25	22	19	20
10	KALIYAMMAL	60/F	42	42	19.8	24	133.8	136.4	32	34	34	33	45	41	51	20	20	22
11	THANGAMMAL	45/F	42	40	21.9	22.7	134.5	139	36	33	37	37	44	41	15	14	15	15
12	INDIRANI	39/F	38	38	22.7	22.7	133	132.5	39	37	33	34	42	41	20	19	20	21
13	BABY	30/F	42	40	24.8	25.5	137.4	141.7	33	32	36	36	47	47	17	19	13	15
14	AMMAKANNU	63/F	38	40	27	29.2	125.2	130.9	28	35	34	37	42	43	27	23	12	13
15	KALIYAMMAL	65/F	40	40	20.6	24	135.8	138.5	32	35	33	33	45	42	23	21	17	19
16	CHINNAMMAL	65/F	40	40	26.9	26.9	129.8	135.7	30	32	37	35	48	43	19	17	28	29
17	SARASWATHY	60/F	40	38	22	25.8	133.9	135.9	33	41	34	36	30	31	17	18	18	19
18	DEVI	67/F	36	40	23	23	140	142	40	40	36	36	47	47	17	18	15	16
19	CHINNATHANGAL	54/F	42	42	30	30	139	139	32	37	37	33	46	48	22	23	16	11
20	PALNIYAMMAL	41/F	42	42	27	25	133	134	36	39	33	34	45	42	20	17	18	19
21	SARASWATHY	60/F	40	40	26	26	130	132	37	41	35	34	36	35	18	19	15	23
22	DEVI	30/F	40	40	27	26	139	140	36	39	36	37	41	41	13	16	13	16
23	PALANIYAMMAL	72/F	42	40	26	28	133	134	35	35	36	36	44	42	19	17	21	19
24	INDIRANI	40/F	38	38	25	23	135	138	37	41	33	36	45	47	18	19	15	23
25	SHOBA	48/F	42	42	23	26	130	132	35	38	34	33	41	40	20	21	23	22
26	MARY	55/F	42	42	26	23	132	139	40	39	34	34	50	50	16	15	22	20
27	CHANDRA	60/F	40	42	26	27	135	139	30	38	37	34	42	42	17	18	19	22

28	AYESHA	40/F	40	42	24	26	130	141	39	38	33	37	44	45	17	15	20	24
29	Thilagamani	35/f	40	40	25	27	139	140	37	37	36	33	43	45	17	17	20	21
30	Karupusamy	75/F	44	48	27	31	136	140	36	37	34	36	53	56	19	16	16	16
31	ARRAMMAL	40/F	40	40	24	23	136	140	34	35	33	34	53	51	18	14	16	19
32	SELVI	40/F	38	38	23	24	137	137	33	41	37	33	39	37	17	17	15	18
33	YAMUNA DEVI	26/F	40	42	25	26	136	137	38	37	34	37	47	47	20	22	11	13
34	THILAGA	45/F	40	40	24	25	139	139	38	37	36	34	47	47	20	22	11	13
35	YAMUNA	36/F	42	42	25	27	134	138	35	36	37	36	46	46	21	20	14	14
36	ANADHI	20/F	36	36	21	21	131	137	37	41	34	37	45	43	16	17	17	16
37	KAMATCHIYAMM AL	55/F	44	44	27	30	127	132	37	31	35	33	42	40	21	21	13	23
38	GURUVAMMAL	85/F	44	44	26	29	139	138	37	28	36	35	45	41	20	22	19	25
39	SAROJA	36/F	44	44	27	30	135	137	39	37	36	36	49	49	18	17	20	24
40	JOTHIMANI	39/F	42	42	27	27	135	130	40	34	33	36	41	44	15	20	18	22
41	MEENAMMBAL	60/F	40	40	25	25	128	134	37	38	34	33	49	47	22	19	20	23
42	ESWARI	36/F	40	42	25	27	122	135	34	35	34	34	42	40	22	19	18	21
43	REGINA	38/F	44	42	30	30	127	130	35	34	37	34	56	53	20	20	19	23
44	SAMBOORANAM	68/F	46	44	28	29	133	133	33	41	33	37	48	47	24	23	12	11
45	RAJATHI	28/F	42	42	26	24	134	138	41	42	36	36	32	51	22	16	22	24
46	SHOBA	48/F	40	40	24	26	127	132	35	37	34	36	42	39	17	17	22	24
47	SBEERA	35/F	44	46	27	22	122	130	39	32	33	33	25	21	17	20	18	19
48	JANSIRANI	35/F	42	40	26	26	135	138	33	37	37	34	51	53	17	18	23	28
49	THILAGAMANI	35/F	38	38	23	25	139	140	42	39	33	34	42	44	19	19	24	24
50	ARRAMMAL	40/F	44	42	22	28	133	132	29	32	36	37	47	40	19	24	16	18
51	ARRAMMAL	64/F	42	42	25	25	132	131	30	33	34	33	45	39	20	18	19	17
52	ESWARI	36/F	42	42	27	28	124	135	37	39	33	36	49	46	17	18	13	14
53	ABDUL SALEEM	23/M	48	46	32	33	130	134	40	43	37	34	50	48	22	20	18	19
54	BABY	34/F	44	44	28	27	128	129	35	38	34	38	46	47	22	22	22	18
55	NATHIRA BANU	25/F	40	40	25	26	131	132	34	33	36	37	44	42	18	15	23	24
56	THILAGA	35/F	40	40	26	25	135	138	33	37	37	34	51	48	20	16	15	21
57	HABIBA	45/F	40	40	26	27	133	139	35	38	34	36	44	39	21	20	22	18
58	INDIRADEVI	55/F	42	42	27	29	140	141	32	41	35	37	45	42	21	19	22	25

59	SANGAMESHWRI	35/F	38	38	22	27	134	138	37	39	36	38	35	37	15	16	18	19
60	SAROJA	54/F	40	40	26	27	130	135	39	37	36	35	40	43	22	22	33	26
61	RANGATHAL	67/F	38	38	22	23	130	135	37	40	33	36	36	33	21	19	19	25
62	RAJESHWARI	53/F	42	42	27	29	127	130	39	39	34	36	46	42	23	20	17	24
63	AMMAKANNU	36/F	42	42	26	29	124	134	30	28	34	37	42	40	23	20	15	15
64	INDIRANI	39/F	38	38	25	23	135	136	32	30	37	34	41	38	16	20	22	22
65	AMEETHA	55/F	40	42	27	31	132	136	32	37	33	34	41	47	17	23	14	17
66	ASIA BEGAM	44/F	44	44	27	30	137	137	38	40	36	39	49	43	23	17	20	24
67	GOWRI	39/F	40	40	24	28	137	138	24	36	34	36	47	48	18	15	28	19
68	JABMALAI	70/F	42	42	28	29	138	139	37	41	33	36	55	51	16	16	14	16
69	KALVIKARASI	35/F	42	42	25	24	134	133	39	39	37	33	48	46	23	21	27	24
70	KAMATCHIAMMA L	55/F	40	40	24	29	126	132	37	31	39	35	39	39	25	18	16	22
71	KARUPPATHAL	60/F	42	42	26	28	136	132	34	34	36	38	47	40	17	21	22	13
72	MEENAMBAL	60/F	38	38	24	24	134	128	37	36	39	37	40	44	22	19	15	17
73	MUMTAJ	55/F	42	42	23	27	136	127	37	31	33	33	35	36	21	23	14	19
74	NELLAMBAL	78/F	40	40	21	24	133	130	38	39	37	36	39	35	21	17	16	21
75	PARIMALADEVI	42/F	40	40	26	26	130	127	37	34	39	38	50	46	28	22	22	22
76	PALANIYAMMAL	42/F	40	40	26	25	136	133	31	35	36	33	44	46	20	20	19	15
77	PREMA	24/F	42	40	24	24	136	135	35	38	37	37	44	45	20	24	22	19
78	PUSHPALATHA	36/F	40	40	27	24	135	133	35	37	39	34	42	40	20	18	14	16
79	RAJESHWARI	53/F	42	42	26	31	128	128	37	38	35	36	43	40	24	21	22	24
80	RAJU	43/M	44	44	30	30	137	137	37	35	36	37	54	47	24	23	20	21
81	RUCKMANI	45/F	40	40	28	28	123	122	28	29	36	38	42	44	25	20	25	24
82	SAKUNTHALA	75/F	42	42	24	24	132	133	40	34	33	35	44	45	20	20	23	23
83	SARASWATHY	55/F	40	40	27	27	126	126	31	34	34	36	42	43	26	27	23	21
84	RAJATHI	28	40	40	27	27	126	126	31	34	34	36	42	43	26	27	23	21
85	SAROJA	55/F	40	40	26	26	133	136	29	34	37	36	42	40	21	20	29	19
86	SHANTHI	44/F	42	40	29	27	126	131	34	37	37	33	43	38	21	19	11	10
87	SUBBULAKSHMI	60/F	40	44	25	31	141	142	37	39	33	34	52	49	19	19	22	23
88	SUMATHI	48/F	42	42	21	25	133	133	39	37	36	39	40	36	19	20	23	26
89	VIJAYA	54/F	42	42	28	29	133	138	34	34	34	37	46	46	20	22	16	16

90	AMMASAI	60/F	42	42	28	29	136	135	31	36	40	39	44	42	25	24	12	19
91	SARASWATHY	50/F	42	42	25	28	130	124	35	36	37	36	43	43	24	27	28	21
92	SAROJA	54/F	42	42	28	30	132	136	33	35	33	33	38	38	25	18	31	22
93	SANGEETHA	65	42	42	26	29	124	134	30	28	36	37	42	40	23	20	15	15
94	SARASU	28	38	38	25	23	135	136	32	30	34	34	41	38	16	20	22	22
95	RAKKAMMA	36	40	42	27	31	132	136	32	37	40	39	41	47	17	23	14	17
96	RANI	45	44	44	27	30	137	137	38	40	37	33	49	43	23	17	20	24
97	SHANTHI	70	40	40	24	28	137	138	24	36	34	36	47	48	18	15	28	19
98	KALAIYARASI	62	42	42	28	29	138	139	37	41	36	34	55	51	16	16	14	16
99	RAMATHAL	55	42	42	25	24	134	133	39	39	37	38	48	46	23	21	27	24
100	VANITHA	36	40	40	24	29	126	132	37	31	40	39	39	39	25	18	16	22
101	MAHENDRAN	44/M	40	40	26.2	26.4	137	142.4	33	38	38	40	50	50	18	15	19	15
102	DHARMARAJ	63/M	44	46	31.1	31.9	140.9	140.5	37	36	44	42	56	56	23	23	18	19
103	VASU	62/M	42	40	25.5	26.4	147.1	144.4	29	36	44	38	48	48	17	17	20	16
104	BALAKRISHNAN	48/M	42	42	20	21.2	128	130	34	34	36	42	47	48	20	15	12	12
105	MAHENDRAN	40/M	44	46	31.9	31.2	142	146.3	34	39	39	38	57	57	19	18	18	22
106	VAIYAPURI	74/M	44	44	26.4	31.8	142	142	33	38	41	45	43	40	19	20	20	24
107	KUMAR	37/M	44	46	27.7	28.4	134.7	136.1	38	36	44	45	47	45	16	16	13	17
108	GANAPATHY	78/M	42	44	31.4	34.7	136.5	141.8	34	36	43	38	57	57	26	21	23	23
109	CHANDRAKUMAR	60/M	44	44	31.2	30.4	138.2	142.3	31	30	37	45	51	53	24	19	16	13
110	MAKBOOL	48/M	44	44	28.3	29.1	138	137.6	37	40	39	42	47	47	17	19	16	10
111	MANIKAM	43/M	46	48	27.6	31.8	142.8	138.9	33	32	41	38	55	55	24	27	16	20
112	THANGARAJ	57/M	44	44	29	30.8	138.2	139.9	34	38	38	40	48	46	23	20	14	14
113	ANGAPPAN	76/M	42	42	32.6	27.5	137.6	136.7	30	37	44	42	50	46	17	15	15	18
114	SHAHUL HAMEED	27/M	44	46	31.2	31	132.1	136.8	38	38	44	38	51	51	21	19	14	14
115	MURUGAN	48/M	44	44	29	33.2	139.5	142.3	33	34	36	39	47	48	16	20	17	22
116	MURUGAN	45/M	42	42	25.5	26.2	144.2	141.6	27	29	39	38	54	53	20	18	17	21
117	MASANAM	58/M	40	42	26.2	29.8	130.5	135.8	36	40	41	44	44	42	24	24	19	22
118	DURAIRAJ	53/M	48	50	32.2	33.3	141.6	140.3	40	38	44	39	65	56	22	27	16	22
119	RAMAN	57/M	40	40	24.8	25.5	141.5	141.2	38	41	43	43	46	46	19	19	16	18
120	BANNARI	42/M	50	50	31.8	33.2	138.8	140.9	42	42	37	40	51	50	25	29	19	15
121	VELAYUTHAM	55/M	44	44	27.7	29.1	139.2	141.4	27	28	39	42	51	44	16	18	14	19

122	DHANDAPANI	46/M	42	44	26.2	29.8	137.2	135.8	34	35	41	43	50	47	22	18	13	14
123	CHINNASAMY	55/M	42	42	26.9	27.2	137	140.8	35	37	36	42	45	45	19	17	14	13
124	RADHAKRISHNAN	40/M	44	44	30.1	31.6	147.3	144.7	39	38	39	43	62	58	23	22	19	17
125	ARUMUGAM	43/M	44	44	26	32	143	142	33	34	41	43	52	51	21	21	19	20
126	MURUGESAN	29/M	42	42	26	24	137	136	38	38	44	42	52	50	22	26	11	13
127	KASINATHAN	48/M	46	48	29	31	135	138	34	37	43	38	45	47	19	23	17	19
128	NAVEEN BHARATHI	20/M	42	42	28	29	139	140	39	39	37	36	53	52	17	18	13	19
129	RAMASAMY	60/M	46	48	32	35	136	138	40	37	39	38	53	50	25	25	16	19
130	KRISHNASAMY	30/M	46	44	33	31	136	139	38	39	41	35	56	59	22	21	16	18
131	RAMACHANDRAN	32/M	48	48	32	33	135	137	40	40	38	39	60	61	27	30	12	11
132	PERUMAL	48/M	44	46	30	30	134	133	39	42	44	38	55	54	21	22	14	17
133	VASUDEVAN	34/M	44	44	28	30	141	141	40	38	36	40	59	54	20	18	15	19
134	SAKTHIVEL	55/M	48	46	28	31	126	130	41	41	39	42	48	50	24	29	28	26
135	RAJENDRAN	55/M	44	44	31	30	142	140	29	36	41	38	57	56	19	19	16	21
136	MURUGAN	44/M	44	44	28	31	133	136	32	33	44	40	49	49	22	23	15	17
137	BALAJI	70/M	44	46	28	31	131	134	24	31	43	42	41	41	27	26	20	22
138	KARUPUSAMY	50/M	48	48	27	32	130	130	27	33	37	38	45	47	23	25	20	20
139	BABU	51/M	44	44	28	32	131	142	35	34	39	36	45	46	19	15	16	17
140	MANOHARAN	52/M	42	43	27	29	130	135	35	37	41	38	60	59	19	21	20	18
141	VEERAPPAN	55/M	42	44	29	26	131	131	40	38	38	35	51	50	29	20	13	10
142	CHANDRAN	67/M	46	46	31	32	135	135	35	36	44	39	51	55	19	22	33	29
143	MUTHUMALAI	45/M	38	38	23	24	142	135	40	42	36	38	43	43	15	20	22	23
144	MOKKAISAMY	55/M	48	46	27	30	137	138	32	33	39	40	46	44	19	20	18	19
145	BABU	46/M	42	42	25	25	135	138	33	37	41	42	51	48	20	16	15	21
146	ESWARAN	56/M	42	42	25	25	132	135	38	38	44	38	43	44	19	18	12	18
147	MOHAMEED YOUSUF	65/M	42	42	28	27	139	140	31	32	43	40	50	51	22	17	14	18
148	PARAMASIVAM	51/M	42	42	26	28	138	142	42	39	37	42	50	50	21	18	16	13
149	GOPALAN	57/M	42	42	27	30	141	141	37	41	39	38	48	49	23	22	20	24
150	SURESH	36/M	42	42	19	24	133	136	32	34	41	36	46	41	20	20	20	22
151	ABDUL SALEEM	23/M	48	48	37	32	128	133	38	41	38	38	51	47	21	16	11	16

152	BABU	46/M	44	44	26	27	136	137	29	31	44	35	52	50	16	15	17	20
153	GANESH	33/M	44	46	28	27	138	137	30	30	36	39	53	54	17	18	16	23
154	IRULAPPAN	59/M	46	46	31	31	138	136	34	32	39	38	49	46	23	21	18	19
155	KUMAR	32/M	46	44	31	29	131	130	36	30	41	40	52	52	23	20	24	23
156	MANIKANDAN	23/M	42	42	29	32	134	131	39	41	44	42	45	41	24	22	11	13
157	NATARAJAN	65/M	40	40	23	22	133	135	36	34	43	38	47	45	19	13	18	16
158	PALANISAMY	65/M	44	46	27	34	133	136	33	35	37	40	57	53	19	22	22	18
159	RAJAN	60/M	44	44	29	28	138	138	41	37	39	42	44	46	28	18	17	16
160	RAJENDRAN	55/M	46	46	33	28	140	138	30	32	41	38	55	52	17	17	16	23
161	SELVAM	38/M	42	42	28	29	133	136	33	26	38	36	44	40	19	19	11	14
162	SUBRAMANI	45/M	46	46	31	31	140	132	33	32	44	38	47	48	20	21	15	23
163	VASUDEVAN	34/M	46	44	26	29	137	139	39	36	37	35	55	47	22	19	18	17
164	VELUSAMY	54/M	50	50	32	34	138	139	29	31	36	39	57	56	24	24	21	21
165	RAJA	60	46	48	32	35	136	138	40	37	36	38	53	50	25	25	16	19
166	KANDHASAMY	58	46	44	33	31	136	139	38	39	39	40	56	59	22	21	16	18
167	KUPPUSAMY	75	48	48	32	33	135	137	40	40	41	42	60	61	27	30	12	11
168	TAMILSELVAN	26	44	46	30	30	134	133	39	42	44	38	55	54	21	22	14	17
169	BALAMURUGAN	35	44	44	28	30	141	141	40	38	43	40	59	54	20	18	15	19
170	KARTHIKEYAN	62	48	46	28	31	126	130	41	41	37	42	48	50	24	29	28	26
171	SATHASIVAM	85	44	44	31	30	142	140	29	36	39	38	57	56	19	19	16	21
172	GOPAL	23	44	44	28	31	133	136	32	33	41	36	49	49	22	23	15	17
173	MAYILSAMY	52	44	46	28	31	131	134	24	31	38	38	41	41	27	26	20	22
174	KESAVAN	63	48	48	27	32	130	130	27	33	44	35	45	47	23	25	20	20
175	RAJESH	44	44	44	28	32	131	142	35	34	36	39	45	46	19	15	16	17
176	SAKTHIVEL	28	42	43	27	29	130	135	35	37	39	38	60	59	19	21	20	18
177	PRABHU	33	42	44	29	26	131	131	40	38	41	40	51	50	29	20	13	10
178	SIVA	51	46	46	31	32	135	135	35	36	44	42	51	55	19	22	33	29
173	SANKARAN	48	38	38	23	24	142	135	40	42	43	38	43	43	15	20	22	23
180	RAMESH	27	48	46	27	30	137	138	32	33	37	32	46	44	19	20	18	19
181	KARTHIK	43	42	42	25	25	135	138	33	37	39	40	51	48	20	16	15	21
182	ANBALAGAN	51	42	42	25	25	132	135	38	38	41	42	43	44	19	18	12	18
183	KARUPPUSAMY	70	42	42	28	27	139	140	31	32	38	38	50	51	22	17	14	18

184	RAMU	63	42	42	26	28	138	142	42	39	44	36	50	50	21	18	16	13
185	SATHISH	29	42	42	27	30	141	141	37	41	36	38	48	49	23	22	20	24
186	MASANAM	65	42	42	19	24	133	136	32	34	39	35	46	41	20	20	20	22
187	KANDHAN	45	48	48	37	32	128	133	38	41	41	39	51	47	21	16	11	16
188	RANGASAMY	38	44	44	26	27	136	137	29	31	44	38	52	50	16	15	17	20
189	MUNISWARAN	71	44	46	28	27	138	137	30	30	43	40	53	54	17	18	16	23
190	YUVARAJ	25	46	46	31	31	138	136	34	32	37	42	49	46	23	21	18	19
191	DHANRAJ	31	46	44	31	29	131	130	36	30	39	38	52	52	23	20	24	23
192	AYYAVU	60	42	42	29	32	134	131	39	41	41	35	45	41	24	22	11	13
193	AMMASAI	45	40	40	23	22	133	135	36	34	38	40	47	45	19	13	18	16
194	THANGARAJ	65	44	46	27	34	133	136	33	35	44	44	57	53	19	22	22	18
195	KRISHNAN	20	44	44	29	28	138	138	41	37	36	43	44	46	28	18	17	16
196	SIVAM	32	46	46	33	28	140	138	30	32	39	39	55	52	17	17	16	23
197	PRABHU	24	42	42	28	29	133	136	33	26	41	44	44	40	19	19	11	14
198	PANEER SELVAM	46	44	46	31	31	140	132	33	32	44	45	47	48	20	21	15	23
199	SRIRAMAN	31	42	44	26	29	137	139	39	36	43	45	55	47	22	19	18	17
200	KUPPUSAMY	65	50	50	32	34	138	139	29	31	37	38	57	56	24	24	21	21
	AVG		42.49	42.69	26.95	28.10	134.65	136.29	34.98	36.09	37.76	37.46	47.45	46.41	20.62	19.76	18.06	19.23

<u>ஒப்புதல் படிவம்</u>

பெயர் :

பாலினம் : வயது :

முகவரி :

அரசு கோவை மருத்துவக் கல்லூரியில் எலும்பு முறிவு மருத்துவ துறையில் பட்ட பயிலும் மாணவன் அவர்கள் மேற்கொள்ளும் "**இடுப்பு எலும்பின் சராசரி அளவிற்கான சி.டி (C.T) ஸ்கேன்**" குறித்த ஆய்வில் செய்முறை மற்றும் அனைத்து விவரங்களையும் கேட்டுக் கொண்டு எனது சந்தேகங்களை தெளிவுப்படுத்திக் கொண்டேன் என்பதை தெரிவித்துக் கொள்கிறேன்.

நான் இந்த ஆய்வில் முழு சம்மதத்துடன், சுய சிந்தனையுடனும் கலந்து கொள்ள சம்மதிக்கிறேன்.

இந்த ஆய்வில் என்னுடைய அனைத்து விபரங்கள் பாதுகாக்கப்படுவதுடன் இதன் முடிவுகள் ஆய்விதழில் வெளியிடப்படுவதில் ஆட்சேபனை இல்லை என்பதை தெரிவித்துக் கொள்கிறேன். எந்த நேரத்திலும் இந்த ஆய்விலிருந்து நான் விலகிக் கொள்ள எனக்கு உரிமை உண்டு என்பதையும் அறிவேன்.

இடம் : கையொப்பம்

நாள் :